IRON AND STEEL ENGINEER

J. F. KELLY, Editor

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Vol. IV. May, 1927 No. V.

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Published Monthly by

Association of Iron and Steel Electrical Engineers

706 Empire Building, Pittsburgh, Pa.

Entered as second-class matter January 25th, 1924, at Pittsburgh, Pa., under the Act of March 3rd, 1879.

Subscription Price $5.00 per Year. Single Copy 50c.

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EDITORIALS

Early History—Steel Mill Electrification

The Iron and Steel Engineer is bringing to the attention of its readers on the opposite page a photograph of what is believed to be the first electrical organization in any steel plant in the United States.

The picture was made up at the time Mr. A. C. Dinkey became Assistant General Superintendent of the Homestead Works, Carnegie Steel Co., in 1899.

A large number of the men shown in this picture are recognized leaders in the Electrical Industry today.

Mr. Dinkey assumed control of the Electrical Department at Homestead about 1890 and this group represents men who were intimately connected with him in more or less important positions during his term of nine years. He is the Dean of the Steel Mill Electrical Engineers, having had charge of the first recognized Steel Plant Electrical Department, and it is interesting to note, at the end of nearly thirty years, how widely scattered and successful this early staff of electrical workers have become. They range from general managers to superintendents of electrical departments, in many different steel plants, while some have remained with the original company and risen to posts of responsibility by regular promotion.

Mr. Dinkey, himself, rose to the position of President of the Carnegie Steel Company, leaving to accept a like position with the Midvale Steel Company.

Chas. Proudfoot, after long and notable service in electrical work, is now General Manager of the United States Ferro Alloy Corporation, in Niagara Falls.

Mr. Chas. A. Menk is now Superintendent of the Electrical Department at Homestead and has had charge of the greatest mill electrification up to this time accomplished in the steel world.

Mr. A. C. Maccoun left the fraternity to adopt the Metallurgical branch, after serving many years as Electrical Superintendent of the Edgar Thomson Works and is now Blast Furnace Superintendent at this plant.

Mr. James Riles is now associated with the A. M. Byers Company, Pittsburgh, Pa., in the capacity of Electrical superintendent.

Mr. Jos. F. Jelly left the Homestead Works to accept a position at the Phoenix Iron Works at Phoenixville, Pa., as Electrical Superintendent.

Mr. James S. O'Donovan rose from the ranks and is now Electrical Engineer of the Spang Chalfant Co. at Etna, Pa.

Mr. Robert A. Menk is now associated with the United States Ferry Alloys Corporation at Bridgeville, Pa., in the capacity of Master Mechanic.

Mr. B. W. Gilson rose in the Carnegie Steel Co. to the position of Director of Light and Power, Youngstown District, Carnegie Steel Co., Youngstown, Ohio.

Mr. Harry A. Cox is now Master Mechanic at the American Steel & Wire Co., Donora Works, Donora, Pa.

Mr. Peter McGrane left the employ of the Carnegie Steel Company to become associated with the Railway Steel Springs Co., Chicago Heights, as Electrical Superintendent.

Mr. S. S. Wales succeeded Mr. A. C. Dinkey as Superintendent of the electrical department at Homestead, Pa., later was appointed superintendent of the Armor Plate Department at that Works, and is now Chief Electrical Engineer of the Carnegie Steel Company, Pittsburgh, Pa.

Mr. Frank W. Jessop entered the commercial side of the electrical business and is now President of the Ohio Electric and Controller Company, Cleveland, Ohio.

Mr. Robert Boak left the Carnegie Steel Co. to become associated with the Edgewater Steel Company as Electrical Engineer and now holds the rank of superintendent of that Company.

Mr. M. S. Robinson accepted a position with the American Steel & Wire Co. at the Donora Works, Donora, Pa., as Electrical Superintendent.

Mr. William Jackson was transferred to the Carry Furnaces as Electrical Superintendent and is now Assistant Electrical Superintendent, Homestead Steel Works, Carnegie Steel Co., Munhall, Pa.

Many left the drive of the mill for the commercial side of electricity. All have progressed to positions of importance and value in their chosen line and some have of course "passed on" having honorably accomplished the work set before them.

Quite a number of these men have served the Association of Iron & Steel Electrical Engineers as President and in various other honorable capacities.

Altogether it is a notable gathering of men, this first general and his staff, in the opening campaign of electricity against the older form of power, who had to accomplish the impossible with scant equipment and few resources.

In 1899, one year after this group was taken, the organization was torn apart by a sudden demand, from all over the United States, for men trained to the needs of mill electrical operation due to the rapid expansion in the use of this power. You will find members of this group "Carrying On" in all parts of the country where steel is made with the same disinterested loyalty, tireless energy and resourcefulness with which they were imbued by Mr. Dinkey's example back in the Homestead Works.

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*Speed Regulation of the Main Roll Drives**

By L. A. UMANSKY†

A. INTRODUCTION

THE speed regulation of any drive, as understood in this discussion, is the change of its speed from full-load to no-load, expressed in percent of the full load speed. For instance, a motor running light at 204 r. p. m. and slowing down to 200 r. p. m. under full load is said to have a speed regulation of 2%. This is the official definition of the American Institute of Electrical Engineers.

This expression should by no means be confused with such terms as "speed range" of adjustable speed drives, meaning the limits within which the speed of a drive may be adjusted at will; nor with the term "close speed adjustment," which defines how closely the several selective speed points may be chosen. In other words, the "speed regulation" is a characteristic of the drive contingent only on the changes of load, for any definite initial speed adjustment.

The majority of electric motors inherently possess good speed regulation. Such expression as "shunt characteristic" entered our language to define a drive which changes its speed very little with a wide variation of load, as is the case with the well-known shunt wound D. C. motor. Or take, for instance, the conventional induction motors. Their full-load speed is only 1 or 2% below the synchronous speed. It is well known that when a larger speed regulation is required, as with flywheel drives,

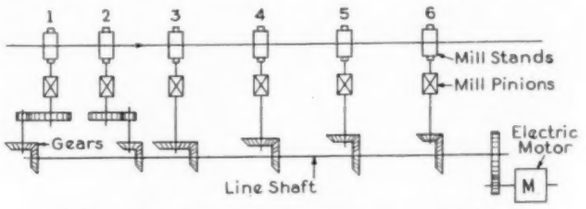

FIG. 1.—Continuous Mill with a single drive.

it becomes necessary to artificially "spoil" the shunt characteristic of the driving motor by providing either an additional secondary resistance (for induction motors), or a series field (for D. C. motors.)#

For a number of years, since the electrification of the rolling mills began, the inherent speed regulation of electric motors was all that was required. Most of the mills maintained their original layouts, and the electric motors were simply substituted for the steam drives. The ability to maintain the speed at all conditions of load was always considered a big factor in favor of mill electrification.

The usual thing happened. The good characteristic and the possibilities of the electric drives permitted the mill designers to radically change the layout of the mills and their mode of operation. This, in turn, imposed new and more exacting requirements on the electric motors.

During the last few years there came in prominence and gained wide popularity a mill of a new type: Continuous mill with individual drives for its several stands. I hardly need to mention the fundamental characteristics and advantages claimed for such a mill.

In the conventional continuous mill (Fig. 1) the several stands are geared to a common line shaft; the latter is driven by one motor. The speed ratio between the stands is fixed, regardless of the speed adjustment—if any—of the motor. This fact fixes the relative delivery speeds at the stands unless the roll diameters are changed. Such mill is hardly suitable for jobbing work; that is, for rolling relatively small orders of diversified products.

Figure 2 shows an ultra-modern continuous mill with separate drives for each stand. The stands are located on short centers. Several mills are operating with 7 ft. to 10 ft. centers and a small mill is known to run with stands only 42" apart. Each drive of such mill is usually of the adjustable speed type; thus they may be considered as flexible gear units between the line shaft and the stands, with the electric power bus taking place of the line shaft itself. Extreme flexibility and ease with which the mill may be adjusted for different rolling schedules is a strong point of such layout, although the total HP capacity of the drives and the cost per 1 HP is necessarily higher than in the first case. Figure 4 gives the view of a motor room of an up-to-date mill of this type.

A compromise layout (Fig. 3) is very widely used. The entire roughing train is driven by one motor, the intermediate train—if any—by another motor, while

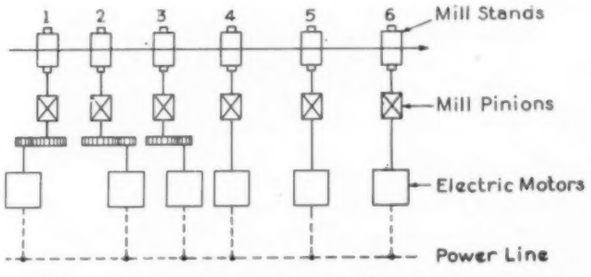

FIG. 2—Modern Continuous mill with individual drives for each stand.

the finishing stands each take an individual drive. Thus maximum flexibility is provided at the finishing end where it is usually most needed and is party sacrificed at the roughing end where it may be needed to a lesser extent. From the standpoint of the first cost of the electrical equipment—everything else being equal—the layout No. 3 is somewhere halfway between No. 1 and No. 2.

From the operating standpoint, the sectionalized drives for continuous mills present great advantages: Small floor space required; finishing the metal while

(#) It is surprising that we still hear, once in a while, such remarks like: "Flywheels are provided so that the motors will not unduly drop off in speed as the steel enters the mill." The cause is confused with the result. It should be well known by this time that an electric drive with a flywheel should have, and usually has, a higher speed regulation specially provided for, than a similar drive without a flywheel.

*Presented before Pittsburgh Section, January 16, 1926.

†Industrial Engineering Department, General Electric Co., Schenectady, New York.

it is hot and, therefore, with low power consumption; flexibility obtainable heretofore only on looping or cross-country mills.

One will readily see that such layouts impose rather exacting requirements on the electric drives themselves. We have just compared these drives with gear units having a flexible gear ratio. We should qualify this statement in a better way: The gear ratio should be "flexible" when we want to change it, and it should remain "rigid" after the change is made. In other words, after the speed ratio between the several stands has been adjusted, the ratio should remain reasonably constant in order to avoid either excessive looping, or stretching of the metal between the stands. It is in this connection that the speed regulation of electric motor is usually brought into the picture.

The inherent regulation of electric motors, good as it is, is not 100% perfect. Only synchronous motors may be said to possess this characteristic; but, such

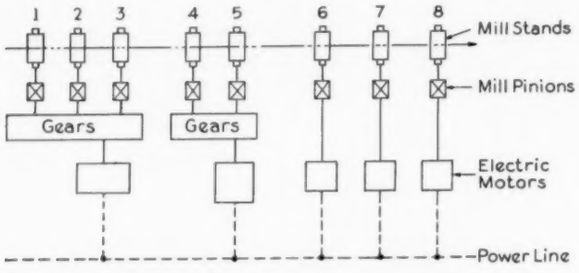

FIG. 3—Modern Continuous Mill with several drives; this layout is a compromise between those shown on Fig. 1 and Fig. 2.

machines are of the constant speed type and they can not be considered when a speed adjustment of the several stands is required. Thus we have to deal with machines which are only nearly perfect and we have to adopt such drives for our purpose.

This brifly outlines the program which will be followed in this discussion:

(a) How close a speed regulation need be provided for sectionalized main roll drives and what determines the required regulation?

(b) What speed regulation may be obtained with the electrical machines as are used for such drives?

(c) Is this speed regulation sufficient to meet the mill requirements? If not, in what cases is it not sufficient?

(d) If the inherent speed regulation is not sufficient for the mill requirements, can any remedy be be applied to still further improve the regulation, and what is the remedy?

B. FORMATION AND CONTROL OF LOOP

General Considerations

Let us analyze what is taking place between two adjacent stands, (A) and (B), see Fig. 5, of a continuous mill, each stand being driven by an individual motor. We will assume that the rolled material is some flat stock, like strip, skelp or sheet bar. Small but not excessive looping is permissible, while any stretching of the metal is to be avoided.

Say, the stands are spaced on $C = 10$ ft. centers. Stand A delivers the stock at, say $V_1 = 1500$ FPM $= 25$ FPS; the stand B takes the stock up at a somewhat lower speed $V_2 = 1470$ FPM $= 24.5$ FPS, in order to form a small loop, which is the best proof that there is no stretching of metal. In other words, the stand A OVERFEEDS to a small extent, and we will express this overfeed (f) in percent of the delivery speed:

$$f = \frac{V_1 - V_2}{V_1} \times 100 = \frac{25 - 24.5}{25} \times 100 = 2\% \quad \text{.....(1)}$$

The overfeed, expressed not in percent but in feet per second:

$$F = V_1 - V_2 = V_1 \times \frac{f}{100} = 25 \times \frac{2}{100} = 0.5 \text{ FPS} \quad \text{.....(2)}$$

Each second there will be ½ ft. of overfeed, which goes into building of a loop; naturally the longer is the piece as it goes through the stand A, the greater is the ultimate loop at the end of the pass, provided

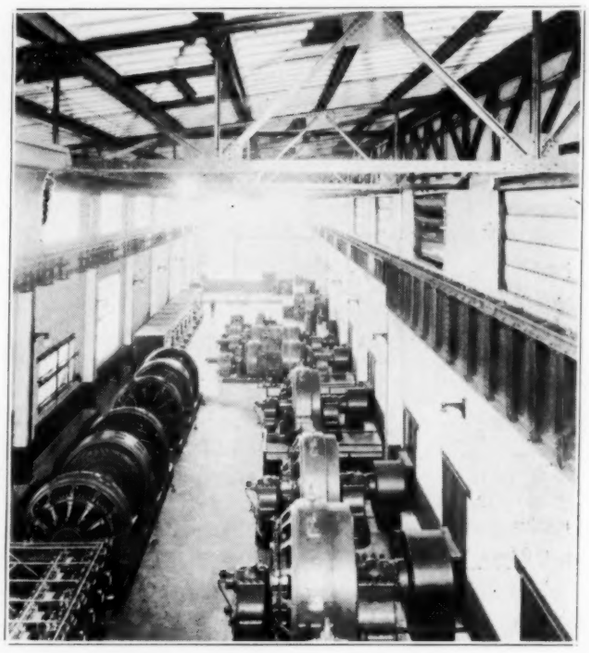

FIG. 4—View of the motor room at the 14" Continuous Mill, Jones & Laughlin Steel Corporation, Woodlawn, Pa. Except for the 3-stand roughing train driven by a 3000 hp motor (not seen on the picture), all other stands are individually driven by separate motors. Total continuous capacity of the drives is over 15,000 hp.

the overfeed (f) remains constant. Suppose the original billet is 1¾" thick and 15 ft. long at the furnace; the gauge at the stand A is 0.090"; thus the total length of the piece going through the stand A is:

$$L = 15 \times \frac{1.75}{0.09} = 291 \text{ ft.} \quad \text{.....(3)}$$

What is the duration of the pass? Obviously, the pass A will last

$$t = \frac{\text{Length in feet}}{\text{speed in ft. per sec.}} = \frac{L}{V_1} = (*) \quad \text{.....(4)}$$

$$= \frac{291}{25} = 11.65 \text{ seconds}$$

(*) Strictly speaking, we should consider for our purpose not the time of pass A, but the time while the metal is in both stands simultaneously; the discrepancy is, however, small and is on the "safe side."

At the end of this period the "½ ft. per second" overfeed will pile up

$$e = F \times t = 0.5 \times 11.65 = 5.825 \text{ ft.} \quad \text{.....(5)}$$

Generally, the maximum amount of the excess stock (we will call it the amount of LOOP) at the end of pass A, is

$$e = F \times t = V_1 \times \frac{f}{100} \times \frac{L}{V_1} = \frac{f}{100} \times L \quad \text{.....(6)}$$

In other words the loop depends only on the length of stock, and on the PERCENT of overfeed, but does NOT depend on the delivery speed. For instance, if we slow down the entire mill 50% or 25% of the actual speed, without changing the drafts, etc., then we will obtain the same amount of loop between any two given stands. We may just as well remember this point. If the looping problem usually acquires more importance at the finishing end of the mill, it is not on account of a higher rolling speed, but because the piece is longer.

If the rolling speed enters at all in the looping problem, it does so not mathematically, but indirectly. For instance, if the speed of the drives need be adjusted either by hand or by any regulator during the pass in order to control the loop, then a lower rolling speed may make the problem simpler.

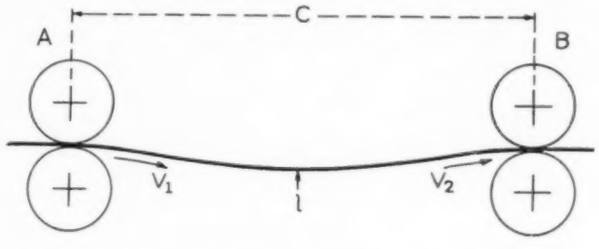

FIG. 5—Loop diagram between two stands of a continuous mill. Stand A delivers the stock at a slightly higher speed than the Stand B takes it up, thus creating a moderate loop.

Speed Regulation and Loop:

Where did the speed regulation of the driving motors enter in the expression defining the loop between the stands? It did not enter at all, nor should it enter in the problem as presented. The loop is created by the difference of speeds V1 and V2 when the steel is in both stands simultaneously; i. e. WHEN BOTH DRIVES CARRY THE LOAD. What are their corresponding no-load speeds, does not affect directly the question of looping. But there still may exist an indirect relation between the two values.

Suppose, for the sake of argument, that the speed regulation of the motor driving the stand B is exceptionally poor; say, the roll speed is 10% higher at no-load than at full load. The full load speeds are properly adjusted and there is, say, a 2% overfeed (i. e. V_2 is 2% under V_1. Now the mental passes through the stand A and hits the rolls B; the latter runs 9% too fast; at that instant

$$V_2 = (.98 \div .9)\ V_1 = 1.09 V_1;$$

before the drive B will slow down under load, there is a certain theoretical possibility of a slight stretching of the metal. To be sure, the process of slowing down under load can not last very long; the inertia of the rotating parts of such drives (which are never equipped with flywheels, of course) is small; for instance, the WR^2 of a 800 HP-275 r. p. m. motor is such that imposing a normal load will reduce the motor speed by 10% in less than 1/10 second; in other words, the period of readjustment (while the speed V_2 changes from 1.09 V_1 to 0.98 V_1) will last only that little; during this period the average speed

$$V_2 = \frac{1.09 + 0.98}{2} \times V_1 = 1.035\ V_1$$

and with $V_1 = 1500$ FPM $= 25$ FPS, the stand B tends to take up $25 \times 0.035 \times 0.1 = 0.087$ ft $= 1\text{-}1/16''$ more stock that is delivered by the stand A. If the stock, while traveling from stand A to B, forms a slight loop, then the required one extra inch may be well taken care of; if this is not the case, and any stretching is not permissible, then these two stands should not be operated as described. In other words, if the speed regulation is as poor as we have assumed, then we should select the full-load speed of the rolls B still lower, i. e., should allow more "overfeed;" this, in turn, will tend to create a larger ultimate loop. In case this is also objectionable, then it seems that something should be done about the speed regulation of the motors.

Presumably reasonings of this kind originated the idea that the loop control and the speed regulation are closely related. As a matter of fact, the described hypothetical stretching of the metal during the small fraction of a second, after it hits the stand B, can hardly ever take place. As will be explained in the following, a load, suddenly imposed on the drive B, will cause its speed to "dip" momentarily, before the speed is restored again. On account of this "dip" the steel is not only not stretched during the

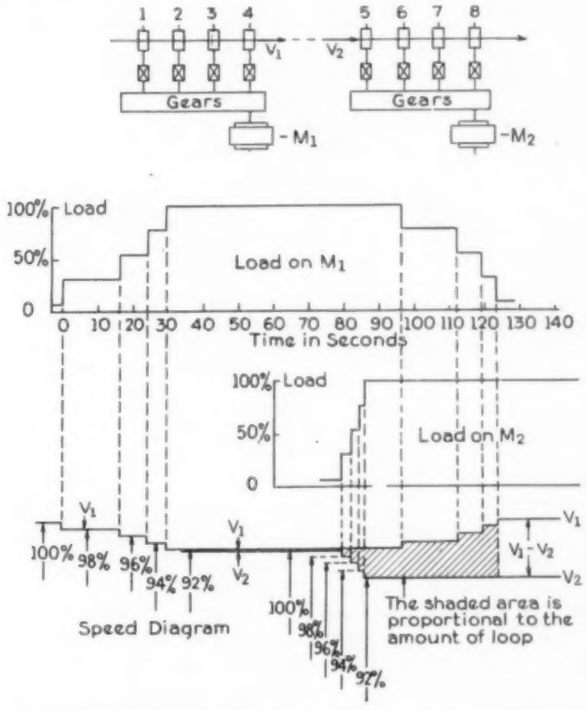

FIG. 6—Study of speed changes and loop formation between two multi-stand trains of a continuous mill; the driving motors are assumed to have a poor speed regulation.

initial period, but—on the contrary—a small initial loop is usually formed, even if the speed of B is adjusted to give no overfeed at all. A MAJORITY OF MULTI-DRIVE MILLS OPERATE IN EXACTLY THIS MANNER: A SMALL LOOP IS FORMED DURING THE FEW FIRST INSTANTS AND IT DOES NOT GROW ANY LARGER UNTIL THE PIECE CLEARS THE ROLLS.

Another argument is sometimes advanced in favor of an exceptionally close speed regulation: It is claimed that it makes possible to accurately set the speed of the several stands before the rolling operations begin and to get in this manner, and without any further adjustment, the proper speed ratio for actual rolling conditions. Such point of view is more optimistic than correct. In order to properly set the mill speed the operator should measure the roll diameter, the draft and then the speed itself. Ordinarily only the first factor may be measured accurately; a mistake of 1/32" in caliperring a 16" roll introduces a very small error of 1/5%. The drafts can hardly be gauged any closer than with an 1% error; what is still more important, the actual draft with the same setting of the screw-downs varies from bar to bar, depending on its temperature; this is well-known to any practical roller. After the necessary mill speed is calculated on the basis of given values of roll diameters and drafts, it should then be set by a speed indicator; the latter can hardly be read any closer than within 1%. Thus, even assuming perfectly accurate guages and tachometers, one can not expect the operator to pre-set the mill speeds any closer than within 2% of the calculated values; he is lucky if he sets them that close.

When the passes are not open, or when other than flat sections are rolled, the active roll diameters can not be determined with the same degree of accuracy; obviously, this makes it still more difficult to pre-set the mill speeds in advance.

In actual practice, the operator sets these speeds more or less approximately and then adjusts them closer when the first or trial bar goes through the mill. More than that—he always has to adjust these speeds under load from time to time, especially at the finishing stands, because of the variations of the steel temperature which affects the drafts.

Thus the speed regulation of the individual drives for a continuous mill is not very strongly related to the problem of the loop control. The importance of speed regulation is sometimes overstressed. One may ask and may even get a regulation of 1/5 of 1%; but, after getting it, one would hardly know how to make much more use of this feature than of a 3 or 4% regulation.

Speed Regulation and Loop in Multi-Stand Trains

If we consider mill drives like the one shown on Fig. 6, then the effect of the speed regulation on the loop may be more pronounced. Let us assume again that the two driving motors M_1 and M_2 have poor regulation like 8%, and that the drop of their speed is proportional to the load.

Suppose the metal fills the stands 1-4, with the finishing stands 5-8 empty; under such conditions the delivery speed of the stand (4) is, say $V_1 = 600$ FPM = 10 FPS. The no-load speed of M_2 is, say, so selected, that even with the finishing mill empty the speed $V_2 = 600$ FPM = 10 FPS. After the metal enters the stand (5), the speed $V_2 = 588$ FPM; after it enters the stand (6)—V_2=576 FPM, after (7)—V_2 =564 FPM; after (8)—V_2=552 RPM. Thus with steel filling both the roughing and the finishing trains, the overfeed is F = 600 — 552 = 48 FPM. After a while the tail end of the bar will clear the stand 1, then 2, 3 and 4; speed V_1 gradually increases, and so does the overfeed. A few simple calculations would show that with the bar 200 ft. long at the stand 4, the ultimate loop is 30 ft. This may or may not be satisfactory, depending upon the distance between the centers of the stands (4) and (5); this distance is usually greater than the possible close spacing of the individually driven stands; the length of the bar is also less after the stand 4 than it might be between, say, the last and the next to the last stands of the finishing mill; so that, by and large, the problem of speed regulation and of looping, with mills like shown on Fig. 6, is usually not more complicated than with the completely sectionalized mills. The assumed speed regulation of 8% is, of course, considerably higher than may usually be obtained.

Drooping vs. Rising Speed Characteristic

In all cases thus far considered we have assumed that the motors have a drooping speed characteristic, i. e. their speed falls off with the load. Some drives, particularly D.C. motors, may be given a rising speed characteristic. Which kind of speed-load curve is more desirable for sectionalized mill drives?

The proper answer depends on the kind of material which is rolled on the mill and on the location of any given drive with respect to other drives at the same mill.

If the material is a flat stock—like we have discussed on the preceding pages—or small rounds, or squares or small shapes—it is usually possible to loop it, while any appreciable stretching is considered detrimental. In such case it is desirable to have the ratio of full load speeds lower than the ratio of no-load speeds between any stand and the preceding one. In other words, if the speed regulation is dropping, then it should be greater on the stand No. 2 than on No. 1, greater on No. 3 than on No. 2, and so on. Or, the roughing drive may have a slightly rising speed characteristic, the finishing mill drive—a slightly drooping one, and the characteristics of the intermediate drives may gradually change in the obvious order. This will insure the formation of loop rather than the stretching of metal. If the material can not be looped at all, but is strong enough to withstand a moderate pull, then the tendency of the speed to droop should be slightly greater, (or the tendency of the speed to rise should be slightly smaller) at the roughing end than at the finishing end of the mill. It is somewhat precarious to give to the drives a pronounced rising speed characteristic; this may cause one drive to take part of the load of the preceding one by pulling excessively the stock between the stands. This would put us face to face with still another problem: That of a relative load control between two or more drives working on the same stock. This problem is usually on hand when the metal is not looped between the stands and when there is no visible indication that each drive is doing only its own share of the work. A drooping speed characteristic is usually the best protection for the motor.

While the load control problem is outside the scope of this paper, a few words may be said in connection with the popular drives for the so-called "edging rolls." These rolls, working on the edges of a flat stock, like skelp, or sheet bar, etc., are not doing much reduction work and require drives seldom exceeding 200-300 HP. The stock is simultaneously in the edging rolls and in the main rolls which may be driven by a large drive of several thousand horsepower. Now, if the speed of the main drive drops off more than that of the edging rolls, there is a danger of severely overloading the small drive by forcing it to push or to pull the main mill.

We should consider it, therefore, as a "birthright" of a relatively small edging roll drive to slow down unler load and to protect itself against taking of more than its proper share of it. If, for instance, the main mill drive has a speed regulation of 3%, it is safer to give to the edging roll drive a speed regulation of, say, 10%.

C. CHARACTERISTICS OF ELECTRIC DRIVES

The Effect of Load on the Speed of a D.C. Motor

Why should the speed of a D. C. motor change when a load is imposed on it? To answer this question thoroughly one should discuss at length a dozen or so of various phenomena, like magnetic and electric densities, flux distortions, commutation and a number of others. However, this paper is not prepared

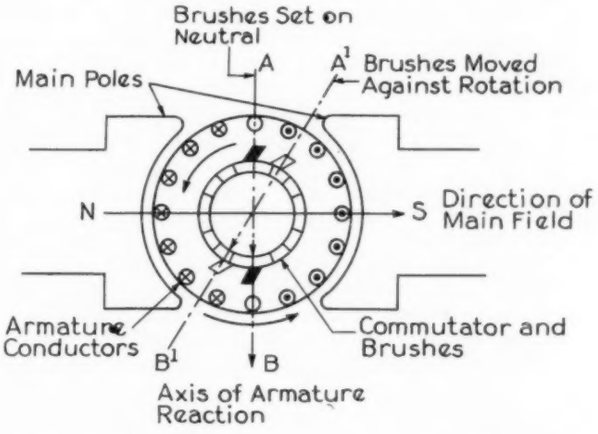

FIG. 7—Elementary diagram of a two pole D.C. motor, showing the direction of the main field and of the armature reaction.

by, nor for, design experts, but for engineers interested primarily in the broad aspects of the motor performance; this will serve as an excuse for considering a rather home-made outline of the problem—crude, to be sure, but workable just the same.

When a load is imposed on a D. C. motor there take place two changes. One of an electrical nature, known as "IR DROP" and another of a magnetic nature, generally called the "ARMATURE REACTION."

If you have a 250-volt motor it may run without load at, say, 400 r.p.m. Now impose a full load on the motor; the full load current flowing through the armature, brushes, commutating field winding, etc., will produce an internal voltage drop of, say 3%, i. e., 7.5 volts; in other words, the full load speed will correspond not to 250 volts, but to only 242.5 volts; if everything else remains unchanged, the speed will drop in proportion to the voltage and will be

$$400 \times \frac{242.5}{250} = 388 \text{ r.p.m.}$$

(Different machines may have higher or lower values of internal IR drop, and the figure of 3% was used merely for illustrative purposes.) But usually "everything else" does NOT, nor can not, remain constant and "its" change also affects the motor speed in one way or another. When the motor is running light, with only very small current flowing through its armature, we may say that the entire magnetic flux is produced by the main shunt field. Now let the current flow through the armature; let us look at Fig. 7, taken from an elementary text book and illustrating a 2-pole motor. The armature winding, surrounding the iron body, acts as a magnet coil; a closer study will show

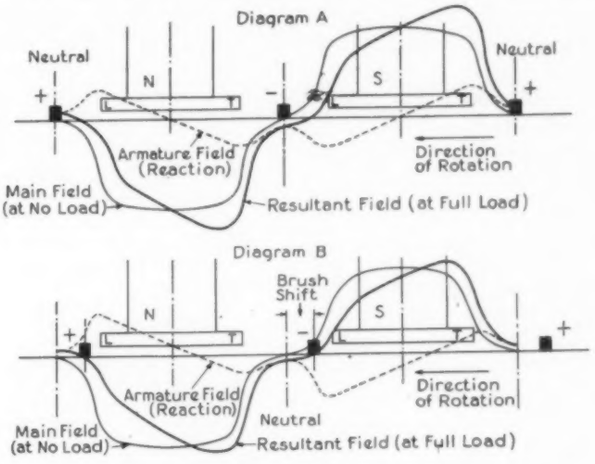

FIG. 8—Diagram showing the effect of motor armature reaction on the distortion of the main field. A—brushes are set on neutral; B—brushes are moved against rotation, increasing the effect of armature reaction.

that the magnetic axis (AB) of such coil coincides with the conductor connected to the commutator bar under the brush; if the brushes are moved to the position A'B', the axis of the magnetic field created by the armature, or THE ARMATURE REACTION, will also move accordingly. At least, this is true as a first approximation. Now, this new magnetic flux does not exist by itself; it interacts and combines itself with the main motor field, and as a result the whole magnetic picture is changed.

Fig. 8 illustrates, in a crude way, this change. Suppose the brushes are set on the neutral, like shown on the upper diagram (A). The curve drawn in thin solid lines is the diagram of the main field; the diagram of the armature field or the armature reaction is shown in dotted lines; the heavy solid line is the resultant field. We see that the armature reaction demagnitizes the leading tip (L) of the pole and magnetizes the trailing end of it (T). Due to the saturation the demagnitizing action is more effective than the magnetizing one, so that the resultant field is weaker than the no-load or main field. Thus the net result is that the armature reaction tends to raise the motor speed, even with the brushes on neutral. With

the brushes moved against rotation (see diagram B) the armature reaction will weaken the motor field and, therefore, will tend to increase the speed to a still larger extent.

In other words the armature reaction may partly or wholly neutralize the effect of IR drop, with the result that by properly setting the brushes the D. C. motor may be given the same speed at full load as it has at no-load. To be sure, the speed-load curve may not be a perfectly straight line; the armature reaction and the IR drop may fully compensate each other at only one value of load, but not at all loads. Fig. 9 gives a speed-load curve of a 500 HP—400 r.p.m. motor; by no means should such curve be considered "typical;" its shape changes from one machine to another, and it is next to impossible to predict this shape accurately.

Brush Shift

Obtaining good speed regulation of a D. C. motor by means of a brush-shift is not a cure-all; those who advocate it as such do not appreciate the importance of the problem which is now discussed. For mills with individual drives, the D. C. motors are invariably of the adjustable speed type; a speed range of 2:1 by motor field control is quite common. Now, you may shift the brushes and obtain zero speed regulation at full field; if, with the brushes left in the same

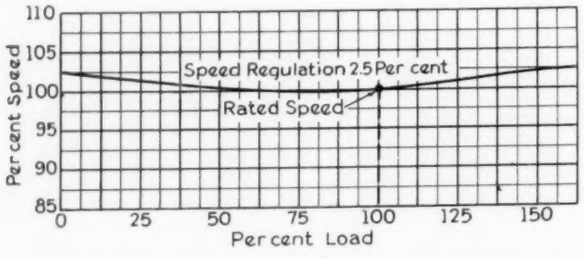

FIG. 9—One of many possible shapes of a speed-load curve of a non-compensated D.C. motor. At first the IR drop predominates and pulls the no-load speed down from 102.5% to 100% at full-load; at a further increase of load the armature reaction may predominate and raise the motor speed.

postion, the motor speed is increased by weakening the main field, the effect of armature reaction will be more pronounced and the speed regulation may become "rising." Naturally, no one would expect the operators to shift the brushes every time the motor speed is changed; a compromise setting is usually adopted which can not, of course, give a 100% perfect regulation at ALL speed settings.

Not so long ago a new type of armature winding was described before this association. Among other things a claim was made that it permits of a wider range of brush shift without impairing the commutation; this, in turn—as was claimed—gives a chance of obtaining good speed regulation. You have already seen that, at best, the brush shift can fully correct the regulation at only one speed point; no type of winding can change the fundamental laws of magnetism and armature reaction. Whatever good regulation was obtained with the then described machines, the type of armature winding has not more to do with it than the kind of paint applied to the magnet frame.

Auxiliary Fields

The use of the well-known compensating or pole-face windings is often useful for minimizing the effect of the armature reaction. When the speed range is very wide (for instance in excess of 2:1) the use of such winding is usually desirable. Its application depends, of course, on a good many other factors, like commutation under heavy load and also on the speed of the motor. A low speed machine usually has a large internal drop and, therefore, it has a drooping speed characteristic; the addition of a pole-face winding still further increases the internal resistance, and may widen the speed regulation. In a high speed machine the internal drop is less and the armature reaction may predominate; a pole-face winding increases the former and reduces the latter with the result that the speed regulation may be improved. A moderate speed machine is usually the most suitable one for obtaining the best all around results.

When part of the motor speed is obtained by the generator voltage (Ward-Leonard) control, the motor speed characteristic is usually dropping at the lower part of the range. It is plain, that the internal drop, measured in volts, will be the same for a given current; however measured in per cent of applied voltage, the IR drop is larger at reduced speed and voltage.

An addition and a proper use of a small series field may help sometimes to improve the speed regulation of a D.C. motor having a wide speed range. Suppose we run, at first, the motor without the series field; by shifting the brushes against rotation we give it a slightly rising speed characteristic at the basic speed; with the same brush shift the regulation will be decidedly rising at the maximum speed. Now let us add the series field; it will "pull" the full-load speed down, counter-acting in part the effect of brush shifting; this counter-action will be, of course, more pronounced at the top speed (weakened main field) than at the basic speed (full main field.) The motor may sometimes be given, in this manner, a fairly uniform regulation at all speed points. In some cases it becomes advisable to adjust the compounding effect of the series field for different speed settings; for that purpose the current flowing through the series field is partly diverted through one or several shunts. The latter may be cut in and cut out either by hand switches or contactors; the first method requires intelligent attention on the part of the operator, who should know which switch to close or open at different motor speeds; contactors may be made to operate automatically from auxiliary contacts of the motor field rheostats. Identical results might be obtained if, instead of a direct acting series field, the main motor is provided with a series exciter.

The latter is a small D.C. generator, either separately driven or connected to the main motor. The armature current of the main motor is used to excite this small additional machine. The armature of the latter is used for energizing an additional field on the main poles of the main motor. If the additional exciter is not a highly saturated machine, the net result is identical to a direct acting series field on the main motor. Its effectiveness may be adjusted by means of a rheostat in the circuit of the auxiliary field energized from the additional exciter; this rheostat may be mechanically coupled to the main speed adjusting rheostat. In this manner when the speed

of the main motor is changed the amount of the "series field" is also suitably adjusted as might be predetermined by tests.

Consistency of Results

It is obvious that the wider is the speed range of the D.C. motor the more difficult it is to obtain equally good regulation at ALL speeds. For a 2:1 motor it is usually possible to obtain a regulation (at ANY point of the speed range) not greater than 3-4%. It is easy enough to adjust the machines on the test floor and to demonstrate much better results; but let me cite on this point Mr. D. Hall (see

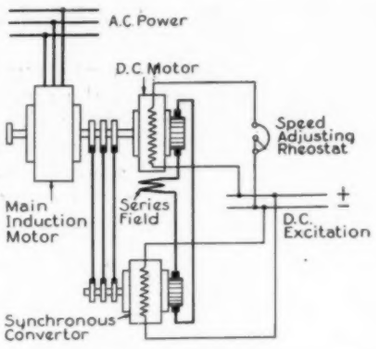

FIG. 10—Elementary Diagram of a Kraemer drive. By shifting the brushes and adjusting the series field of the D.C. motor the speed regulation may be controlled in the same manner as with D. C. drives.

Iron and Steel Engineer, November, 1925, page 457): "If you could maintain a perfect brush fit you might maintain the same speed condition, but where the brushes are loose in the holders and the commutator a little rough, the brushes may bear on the toe more than on the heel, or visa verse, and the armature reaction will not remain the same. Consequently, the speed will be modified. We all make the best brush rigging that we can and we endeavor to obtain good brush fit, but under the best conditions you will find variation from day to day."

To such true statement of facts we all should subscribe. Steel mills can not well afford to constantly "manicure" their motors in order to maintain under actual conditions the excellent speed regulation exhibited on demonstration tests. We may just as well face the facts as they are, check whether the motors will do the expected work without "manicuring," and if we find that the speed regulation (in exceptional cases) will not be good enough, then we have to think of other means of improving it.

Examples of Speed Regulation of D.C. Mill Motors

The story would not be complete if I would not give several examples of what was actually obtained with D.C. motors designed for mill drives of the considered type.

An 800 HP-256/512 RPM-600 volt motor has shown an inherent speed regulation of 0.4% at 512 RPM and 0.2% at 256 RPM; the load has been changed from 100% to friction load and, of course, the brush position has not been changed when the speed was adjusted.

A 1250 HP-175/350 RPM-600 volt motor, with a fixed position of brushes, has shown 1.41% regulation at top speed and 1.02% at its basic speed.

Both above motors comprise part of the electrical equipment driving the 14" hot strip mill of the Trumbull Steel Company. The above figures were obtained on the test stand. It is not claimed that these motors maintain such remarkable regulation from day to day; but their actual performance is excellent because they run under speed regulating conditions as severe, or more so, than any other known mill motors. To this equipment we will revert again later.

A 2100 HP-150/460 RPM motor, one of those shown on Fig. 4, was adjusted to give a speed regulation of 3.5% at basic speed and 0.65% at the maximum speed; note that this motor has a very wide speed range (over 3:1) by motor field control.

Nature of the Initial "Dip" in Motor Speed

Those who have observed mill drives have probably noticed that, when the load is suddenly applied to a drive, there is an instantaneous "dip" of the motor speed, lasting a fraction of one second, after which the motor comes back to the speed, corresponding to the value of load. This "dip," to which we have already referred, may be explained by two factors.

In the first place, a sudden change of current, combined with the reactance of the entire circuit, causes a reactive voltage drop with the obvious effect on the speed; this is a phenomenon of a very short duration.

Secondly, the IR drop takes effect immediately while the counter-balancing action of the armature

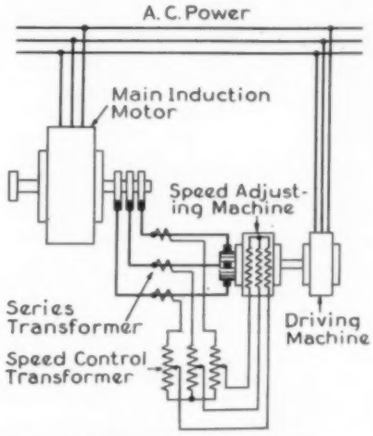

FIG. 11—Elementary diagram of a Scherbius drive. Brush shift and a series transformer may be used for adjusting the speed regulation.

reaction, being of a magnetic nature, takes a little time to make itself felt.

As was already pointed out, the result of the described "dip" is, on the whole, beneficiary as it tends to form an initial loop and this tendency counter-acts the possibility of an initial stretching of the metal.

Speed Regulation of A.C. Drives

The ordinary slip ring induction motor possesses an inherently drooping speed characteristic. The motor should slow down under load in order to permit an increase of the current required to overcome

the imposed load; the slip is almost directly proportional to the load and its value depends on the amount of the secondary resistance.

Any of the known systems of A.C. adjustable speed drives, under ordinary conditions, magnify this characteristic of a slip ring motor. Let us take for example the conventional Kraemer drive (Fig. 10.) The addition of the synchronous converter and of the D.C. motor to the secondary circuit of the main motor can not but increase the resistance of that circuit; therefore, a larger drop in speed will be required to circulate the current required by a given load. If the D.C. motor has a cumulative series field, in addition to the shunt field, then the counter-e.m.f. generated by the motor and injected in the secondary circuit increases with the load; therefore, the drive should slow down still more in order to circulate the necessary current through the secondary circuit; this is usually done with flywheel Kraemer drives.

It is perfectly feasible to give to the D.C. motor a "rising" speed characteristic, i.e., to cause the load to weaken somewhat the motor field; brush shift or a small differentially connected series field may accomplish the purpose. The weakening of the motor field with the load will reduce the counter-EMF so that the drive may not have to slow down as much —if at all—to circulate the necessary current through the secondary circuit. By going still farther in the same direction it is possible to give to the entire drive a rising speed characteristic. This, however, may prove to be not quite desirable with a Kraemer drive; if it runs near its maximum speed, i.e., with a rather low frequency at the synchronous converter, the imposed load will then tend to still further reduce that frequency and may cause the converter to fall out of step.

With the Scherbius drives, like the one shown on Fig. 11, the inherent slip, i.e., the speed regulation, is also somewhat larger than with constant

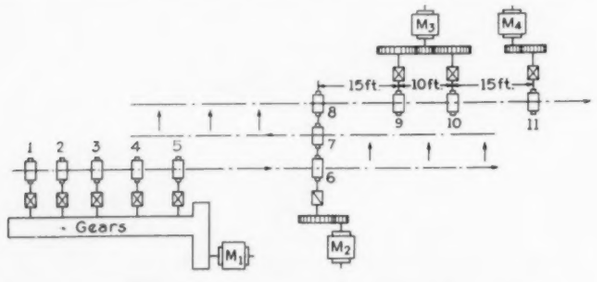

FIG. 12—Layout of a 16" Hot Strip Mill driven by four Scherbius equipments. Stands 8, 9, 10 and 11 are arranged in tandem and are driven by three different motors. Although these stands are very closely spaced, the loop control is very satisfactory and the mill is in successful operation for a number of years.

speed induction motors because there is more resistance in the secondary winding. By shifting the brushes of the speed adjusting machine, the desired compounding (or differential) effect may be obtained for reducing the regulation. It is also possible to provide, for instance, a differentially connected series transformer in the excitation circuit and to control in this manner the speed regulation of the drive.

On the whole the A.C. adjustable speed drives may be readily built to give a speed regulation within 3-4%.

Here again the facts are more convincing than the abstract reasoning. Fig. 12 shows a hot strip mill, all four drives of which are of the Scherbius type. Although the mill itself is of a cross-country type, the last four stands constitute in reality a continuous mill with three separate drives; the stands are located on quite short centers; the delivery speed is up to 1200 FPM. The mill is in operation for a number of years and the speed regulation is quite satisfactory for this application.

D. EXTERNAL MEANS OF IMPROVING THE REGULATION

I believe that such inherent speed regulations as can be built-in and maintained in the electric motors themselves should fully meet the rolling requirements of almost every mill. If the regulation is not over, say, 3-4% at ANY speed setting, then the operators should not experience any trouble with the looping, even though the stands are spaced as closely

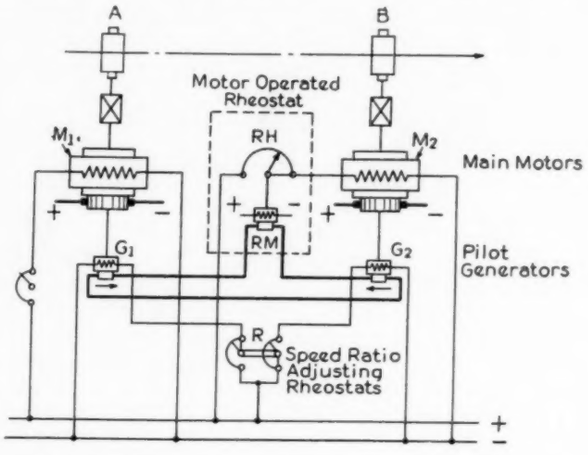

FIG. 13—Elementary scheme for controlling the speed ratio of two drives. The "differential principle" is applied, utilizing the balance of voltages of the pilot generators G1 and G2.

as practical (10-15 ft.) and even though the rolling speed is as high as 2000 or 3000 FPM.

But I readily admit the existence of rare individual cases, where such speed regulation is not, or is not considered to be, close enough; for instance when the stock can not be looped at all, lest it be damaged, and when at the same time it should not be stretched. Can the speed of the drives be maintained with such accuracy as ½ or 1/5 of one per cent?

There should be no problem in electrical engineering that could not be solved if you put it up to a group of engineers and back them up with the necessary research and manufacturing facilities.

When the problem of providing good speed regulation presented itself, the engineers brought about a number of schemes, some of which differ in their underlying principles, some in mere details. It will be outside the scope of this discussion to describe all of these schemes; I will merely outline the basic ideas of the few and will try to point out the strong and the weak points of these.

Differential Principle

For illustrative purposes I will select a D.C. drive. Two mill stands, A and B, (Fig. 13) are separately driven by D.C. motors M1 and M2. Suppose the inherent regulation of these machines is fairly good, like 2-3%, but due to some local conditions this is not considered to be close enough. What is really wanted is to hold the SPEED RATIO between the two stands constant within, say, ½ of 1%, regardless of load, voltage, etc. Obviously, the first thought is to control automatically the field of one of the motors, or of both, whenever the speed ratio changes.

Fig. 13 shows a diagram of connections of an elementary arrangement. Each motor is equipped with a pilot generator, G-1 and G-2; these are in this case D.C. machines, separately excited; their armatures are connected differentially to each other and in series with a pilot motor (RM) on the field rheostat of the motor M2. Suppose the motor M2 slows down; then the voltage of G-2 is reduced; that of G-1 overcomes it and causes RM to rotate, weakening the field of M2 until the proper speed ratio and, therefore, the balance of voltages of G-1 and G-2 is re-established. Obviously the reverse process will take place if the motor M2 speeds up or M1 slows down. By readjusting the rheostat R any other ratio of speeds of M1 and M2 may be selected and then maintained.

Such regulator, if built in the described crude way, may not be sensitive enough for certain applications; a small difference of voltages of the two

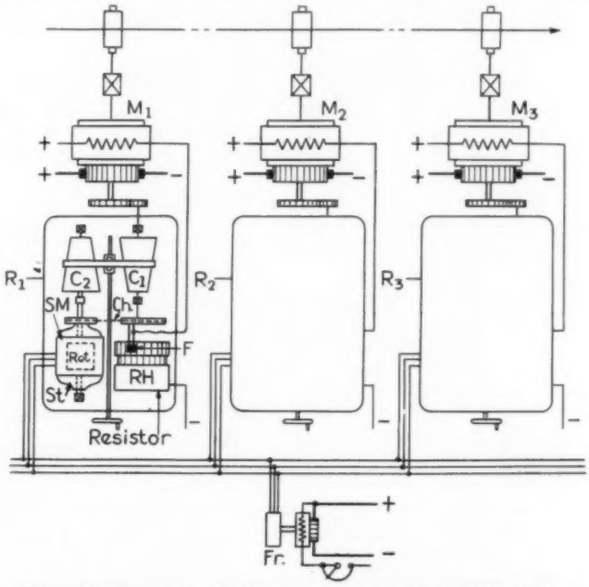

FIG. 14—Layout of Dynamometer Type Regulators for maintaining the speed ratio of several drives. This device is based on matching the frequencies and, owing to its precision accuracy, is widely used for paper mill drives.

pilot generators may not cause the motor RM to move at all; if moved, it may stop either before or after the balance is re-established. In other words such regulator, in its simple form may be suitable for coarse speed ratio adjustment and leaves something to be desired for applications where very fine adjustments are required. The scheme is outlined to merely illustrate the "differential principle"

Dynamometer Regulator

Another speed ratio regulating scheme will be presently described; it is based on the principle of maintaining the balance of frequencies, instead of that of voltages, and is widely used in sectionalized paper machine drives; it has been termed the DYNAMOMETER TYPE of regulator. The paper mill, where no looping is allowed between the stands and where the tension should be very moderate, re-

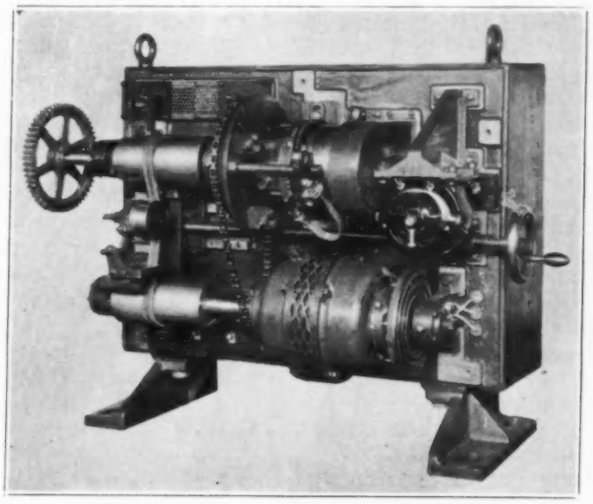

FIG. 15—General view of a Dynamometer Type Speed Ratio Regulator schematically shown on Fig. 14.

quires an exceptionally accurate relative speed control which is of a far more importance than the one ordinarily needed in any steel mill.

Each of the three D.C. motors, M1, M2 and M3, see Fig. 14, (there may be as many of these as you wish) is connected to its regulator R1, R2 and R3. The shaft of M1 is shown geared to the cone pulley C1, which is belted to the second cone pulley C2. The latter is mounted on the shaft of the rotor of a small (1/16 HP) synchronous motor SM; the stator "St" is of the revolving frame type, being free to rotate in ball bearings; it is connected through a chain (Ch) to the brush (F) of a commutator type field rheostat (RH.)

The stator (St) of the synchronous motor is energized from a small 'master" frequency changer set Fr. When the frequency thus applied to the stator corresponds to the rotating speed of the rotor, the revolving frame (St) remains stationary in space, and the setting of the rheostat is not altered. Suppose M1 tends to slow down; as soon as the angle of displacement between (St) and (Rot) will exceed a very small value, there will be the full torque of SM available to move the rheostat RH, in the sense of speeding the motor M1 up; thus the balance will be re-established. Actually much less than ½° displacement is required to cause the rheostat to move; this makes the outfit exceptionally sensitive to the change of speed ratio. Once the speed ratio between the stands is selected, the regulators will maintain it strictly constant, regardless of load, etc. By reducing the frequency of the master set we will slow the whole mill down, still maintaining the selected speed ratio between stands. If the ratio should be altered, the position of the belt on the

cone pulley may be changed, either by a hand mechanism or by an electrically operated device.

A scheme based on matching of frequencies is inherently more accurate than the one using the balance of voltages. The effect of the saturation, of the resistance changes, etc., is entirely eliminated; it is truly a synchronous tie, an "electrical differential" which is as positive as a mechanical differential gear. Its sensitiveness is not 99%, nor 99.9%; it is 100%.

The process of making the paper is continuous; the stock is many miles long; even a slight inaccuracy of speed ratio between the several sections will produce an appreciable cumulative error, which can not be tolerated. Hence the reason for the development of the described regulators which operate with the highest degree of precision known to the engineering art. Fig. 15 shows an assembled speed regulation with cover removed; Fig. 16 illustrates a paper mill installation with a number of such regulators.

In rolling steel we deal with a stock of much shorter length; a length exceeding 1000 ft. is seldom encountered. Therefore slight changes in the speed ratio can not produce the same cumulative error as in the paper mills; the rolling of each new bar starts with a "clean slate." This permits the use for certain cases of steel mill work of other devices, inherently not as sensitive as the paper mill regulators, but possessing other advantageous features.

Vibrating Type Regulators

The regulators of the vibrating type—like the well known voltage regulators—may be readily applied for speed control of the steel mill drives. The main roll motor, the speed of which should be maintained within narrow limits, is provided with a small

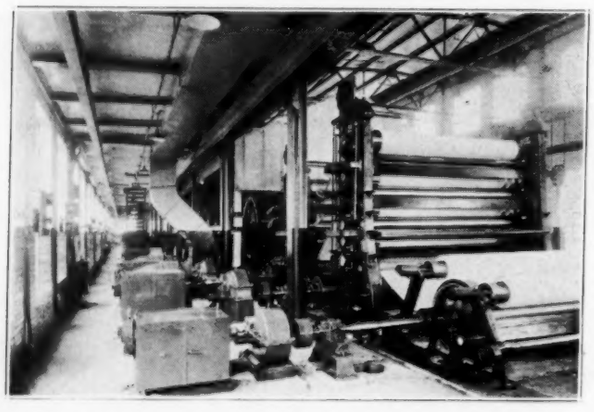

FIG. 16—View of a sectional paper mill drive looking from reel end. Each drive is equipped with dynamometer regulator (mounted in enclosing cabinet at left side) for maintaining constant speed ratio between sections.

pilot generator, separately excited from a constant potential source; thus the voltage of the pilot machine is the direct measure of the main motor speed. This voltage is brought to the voltage regulator; the latter tends to hold it constant by acting on the field of the main motor and holding, therefore, the speed of the motor constant.

Regulators based on this principle were designed and built for hot strip mill drives of the Trumbull Steel Company.

The four roughing stands of this mill are driven by 1250 HP-175/350 r.p.m. motor; a duplicate motor drives the intermediate stands 5 and 6. The four finishing stands are each driven by 800 HP motors with a 2:1 speed range. All motors are operating from a common 600 volt bus, furnished with power from (2) 2300 KW generators. The delivery speed of this mill is up to 2000 FPM; the stands are very closely spaced; the strip is finished in lengths up to 1000 ft.

This mill, laid out prior to 1920, was a radical departure from anything attempted heretofore. Ultimate care was given to insure the success of the mill and the speed regulating requirements were exceptionally rigid; the electrical manufacturers laid out the equipment to hold the speed of the drives within 1/5 of 1% of the setting. Naturally, if such accuracy was asked for, it was necessary to provide external speed regulators.

It was decided to hold the speed of each of the six motors constant and to maintain in this way the constant speed ratio between the stands. The arrangement of the regulator is illustrated on Fig. 17.

Only one out of the six duplicate equipments is shown. Direct connected to the mill motor M is an A.C. pilot generator G, separately excited from a constant potential source. It is the voltage of this

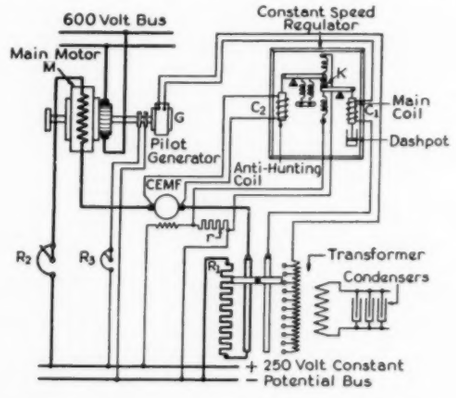

FIG. 17—Diagram of connections of a special constant speed regulator of a vibrating type. On account of the special arrangement of its circuits the regulator had proven to be exceptionally sensitive and quick-acting.

generator that the regulator maintains constant by controlling the speed of the main motor. The use of A.C. pilot generators was preferred in order to eliminate the possible effect of the residual magnetism in the magnet C-1.

The main motor is energized from the 250 volt constant potential bus; a motor operated field rheostat (R1) and a hand operated rheostat (R2) are used for coarse and fine speed adjustment. In addition to it there is inserted in the field circuit a small, so-called "counter-EMF" generator (CEMF), separately driven. The regulator acts on the field of this machine and adjusts thereby the excitation of the main motor; this permits the regulator to handle small currents only.

The pilot generator G energizes the main coil (C1) of the regulator. If, for instance, the motor (M) runs too fast, the main contacts (K) close as we will see later; this short circuits the resistor (r) in

the field of the counter-EMF generator; the field of the main motor is strengthened; the motor slows down. If it slows down too much, the voltage of (G) drops, the contacts (K) part company, the motor field is again weakened, the motor speeds up. In actual operation the contacts (K) make and break the circuit several times per second, cutting-out and cutting-in the resistor (r). The proportion of the time "out" and "in" determines the average value of this resistance and, therefore, the average value of the motor field. The rheostat R_2 permits holding the regulator within its operating range.

It is obvious that such regulators, like all devices of the vibrating type, are extremely quick acting. Their inertia is negligible; in one jump they go from maximum to minimum value. They possess the precious feature of "forcing" the motor field in order to get a quick change of it. For instance, with the resistance (r) permanently cut-in, the motor speed is, say, 450 RPM; with this resistance cut-out the speed is, say, 350 RPM; suppose the motor runs at 400 RPM and, therefore, the contacts K are open or closed 50% of the time. Now suppose that for some reason, like heavy load, etc., the motor speed drops to, say, 390 RPM; the contacts K immediately open, all resistor (r) is cut-in and the motor field is sufficiently weakened to "shoot at the 450 RPM mark." However, just before the motor speed reaches 400 RPM, the voltage of the counter-EMF generator is already suitably lowered, and, therefore, the diminished pull of the coil C2 causes the contacts K to close again; the acceleration stops at the proper instant. The motor was "forced" to accelerate as if it really had to go to 450 RPM; the rate of acceleration was, therefore, much higher than as if we had aimed at 400 RPM which we actually needed. At the same time the coil C2, acting just before the proper speed is reached, provided the anticipating function; it prevented, therefore, the overshooting or "hunting" of the device.

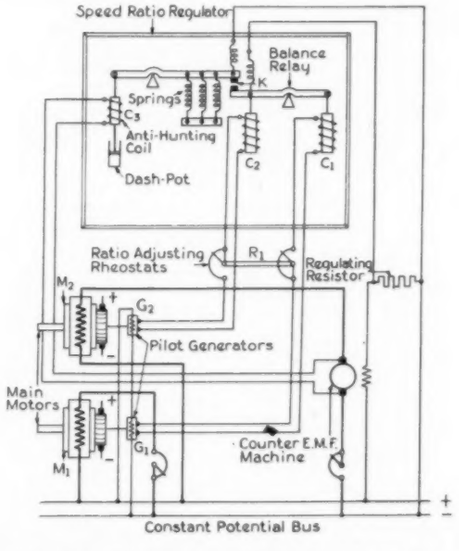

FIG. 18—Elementary diagram of connection of a speed ratio regulator of a vibrating type. A photograph of similar regulator is represented by Fig. 19.

The accuracy of the device depends, of course, on how sensitive is the pull of the coil C1, to the change of speed of the pilot generator. In the Trumbull installation this sensitiveness was greatly augmented by a rather ingenious arrangement. We will note that the controlling circuit goes through the primary of a small transformer T and closes through the main coil C1; the secondary of the transformer is loaded on condensers. Now, if the speed of G increases, the frequency goes up and so does the admittance of the circuit; the power factor of the circuit becomes more leading, and this, in turn, excites the generator G. All these factors act cumulatively and a very small variation of speed causes an appreciable change of current in the coil C1.

FIG. 19—Vibrating Regulator for holding a constant speed ratio between several steel mill drives.

When the speed of the drive need be changed, the rheostat R-1 is moved. If the latter were entirely independent of the regulator, any change of the motor field by the rheostat would be opposed by the action of the regulator, which tends by all means to maintain constant the voltage of the generator G by acting on the field of M. To take care of this point the transformer taps are changed simultaneously with the movement of the rheostat R.1; this changes suitably and automatically the setting of the coil C1, whenever the speed of M should be changed. A fine adjustment of the regulator setting is possible by means of the rheostat (R3) controlling the excitation of the pilot generator (G.)

The accuracy and the speed of operation of the regulators, just described, was truly remarkable. A motor, which would normally drop 1% or 2% in speed when the load would come on, would hold the speed almost as steady as a synchronous motor; the speed of the regulator was such that the motor would not lose more than ¼ of 1 revolution during the "readjustment period;" this means that with 14" rolls, less than 1 ft. of excess material would form between stands.

After the mill was put in operation and was run for awhile, with the regulators working without mis-

hap, it was tried out and found possible to operate with the inherent regulation of the motors only; from that time on the mill is run in this manner. To be sure, the regulation of the motors was exceptionally good and this fact made it possible to get along without any external "medicine."

The vibrating type regulator may be just as well built for maintaining a constant SPEED RATIO between the several drives instead of holding constant the speed of each; this is diagrammatically shown on Fig. 18. The main element of the regulator is then made of the balance relay type; coils C1 and C2 are energized from pilot generators driven by the motors, the speed of which is to be kept in constant ratio. The ratio itself is adjusted by the small rheostats R1; C3 is the anticipating or anti-hunting coil; the contacts K act directly or indirectly on the motor field. It depends on local conditions whether a "constant speed" or a "constant speed ratio" regulator is the best for a given job. The operating characteristics of either are about the same.

If such hair-splitting accuracy as 1/20 or 1/10 of 1% is not required and, say, ½% is satisfactory then the vibrating regulator equipment may be built much simpler than the Trumbull outfit; transformer (T), loaded on condensers, may be omitted. A simplified constant speed ratio regulator is shown on Fig. 19.

Essential Characteristics of Regulators

This brief outline was not intended to cover the multitude of speed regulators, built or conceived. Those which were described were used to point out the salient features which should be incorporated in any well designed equipment.

A most sharp distinction must be drawn between two independent features of a regulator, although both of them contribute to the accuracy of the results.

The FIRST is the sensitiveness of the device, i.e., the per cent change of the controlled value, which change causes the regulator to start its action. For instance, the sensitiveness of an ordinary vibrating regulator is about ½—1%; that of the dynamometer or paper mill regulator is measured by an infinitely small fraction of 1%.

The SECOND feature is the rapidity of action as opposed to sluggishness; obviously the most sensitive regulator, detecting the slightest change of speed but slow in correcting this change, will not prevent a growth of a perceptible cumulative error.

These two characteristics may or may not coincide in the same device. The lack of either will make the regulator inadequate. What we call "accuracy" is our appraisal of the ultimate results; if, for instance, a speed regulator at any time allows a 3% momentary deviation from the set value, then its accuracy—or rather inaccuracy—is 3%. In this sense the same regulator may be a highly accurate device for, say, controlling the speed of a mill, rolling long stock with gradual variations of load—and fall short of expectations if applied to a mill rolling much shorter bars, but with the load varying in a more sudden manner. The success or failure of a regulator depends not only on its design and construction—but depends to a very large extent on its application.

E. CONCLUSION

What is the conclusion that we should draw from this discussion?

In the FIRST place it has been pointed out that the speed regulation is only indirectly related to the problem of maintaining the loop and, therefore, to the question of operating the mill.

SECONDLY, we have seen that the inherent speed regulation of the available D.C. or A.C. drives, although actually not always as good as can be demonstrated on a test stand, is satisfactory for most mills; the motors deliver the goods.

THIRDLY, the electrical profession is ready, whenever it is found essential, to provide artificial means for improving the regulation and to do so with an accuracy far in excess of any reasonable demand.

But to the last, or FOURTH conclusion, I want to point out especially: There is no use for calling for such close regulation which is in excess of the actual requirements. Little is the glory of having a special equipment built and then to get along without it. The real merit of the engineering skill should be measured by the simplicity with which good results are obtained.

Drives for Power Plant Auxiliaries

By F. T. LEILICH*

THE selection of the best form of drive for the auxiliaries of a boiler plant is essentially an economic problem. It falls upon the engineer to make a careful study, considering investment costs, operating costs, reliability, simplicity, and such other intangibles as apply to the specific case. No general statement as to what is the best can be made, as the conditions are different for practically every case.

The advent of increasing steam pressures and the general adoption of the regenerative cycle have undoubtedly had a material influence on the increasing use of electrically driven auxiliaries. A number of the factors contributing to the increase in the use of electricity are:

a. Elimination of steam supply and exhaust lines with attendant maintenance.

b. The general adoption of the regenerative cycle with the easier control of the heat cycle when it does not have to economically utilize exhaust steam from small units, the steam requirements of which are not proportional to the output of the main generators.

*Consolidated Gas Electric Light & Power Co., Baltimore, Md.

c. The relatively high overall economy of the electric drive, as with shaft driven auxiliary generators, the steam requirements for auxiliary power are those of the main unit.

d. Flexibility and reliability of electric motors and control when designed for the job.

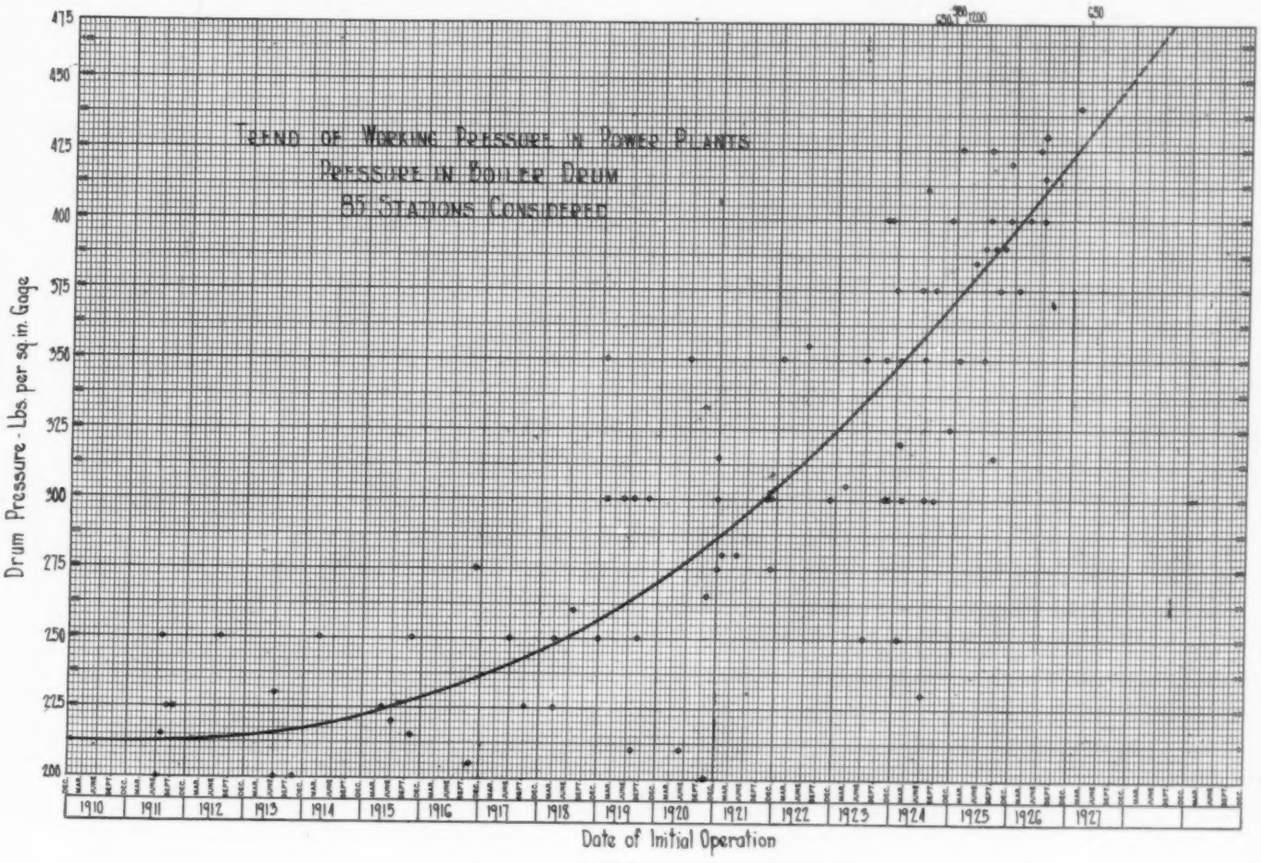

FIG. 1.

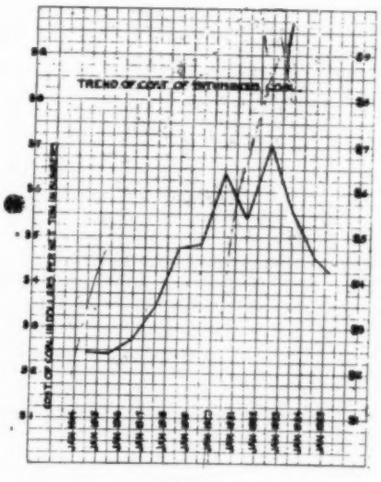

FIG. 2.

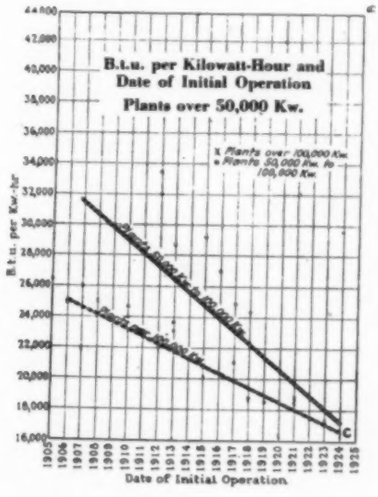

FIG. 3.

The steady climb upward of the steam pressure is shown by Fig. 1, which is a graph showing drum pressure against date of initial operation for 85 modern stations. In this connection, Fig. 2, showing the rise of coal costs, is interesting, and the engineers' answer is shown by Fig. 3, which shows that with the rise in coal cost, fuel per unit output (B.t.u. per kw-hr.) has been coming down. Fig. 4 shows graphically the performance of a number of representative stations of 15,000 to 50,000 kw. With the improvement in performance, there has, however, been an increase in station costs as shown by Fig. 5. Operating costs have not risen in the same ratio as investment costs (fixed charges), and constitute less than 10% of the total cost, so that if the engineer installs an expensive system of control to save on operation, he must not overlook the fact that the reduction in cost of operating labor can apply to only a small part of the whole cost, while his investment is there for the life of the plant, and the charges for

the latter are of the order of 50% of the total. Fig. 6 shows the trend of operating costs. The engineer can produce his greatest showing in returns per dollar invested by making the equipment work longer hours and harder. This means install the best apparatus and operate it at a high use factor—perhaps sacrificing a little in operating efficiency when it is called upon for extra duty during short periods.

The tabulation, Fig. 7, gives a fairly representative cross-section of the auxiliary drive selections for the more recent utility stations. Improvement in smaller turbines will undoubtedly retard the swing

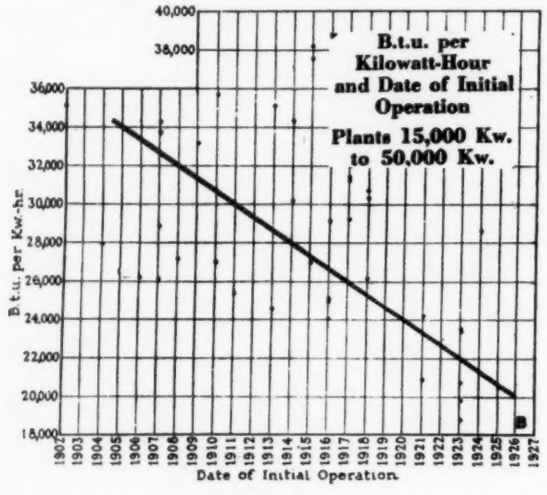

FIG. 4.

toward universal adoption of electric drive, as the new East River Station of the New York Edison Company has turbine driven circulating pumps, boiler feeds, hot well pumps, fans, and other auxiliaries.

Electric drive may be broadly divided into two classes—A.C. and D.C. Fig. 7 shows that A.C. has been chosen in the greater number of cases. The following brief review of some of the advantages of each type of electric drive will serve to bring out the high points affecting a selection:

A C.—Available up to a capacity far in excess of auxiliary requirements, if transformers are used.
Relatively low costs of motors and control for applications with small ranges of speed control.
Absence of commutators (excepting brush shifting motors) and elimination of sparking, which is highly desirable in a pulverized fuel installation.

D.C.—High efficiency possible over wide ranges of speed, which makes the D.C. very attractive in a station operating over wide ranges of rating as the maintenance of proper combustion conditions necessitates a large speed range on forced and induced draft fans, stoker motors and pulverized fuel feeders.

The tabulation shows that 2200, 440, and 220 volts are the prevailing A.C. potentials and 250, the D.C. The selection of the proper voltage is a problem for each installation. I think we can dismiss D.C. for 550 volts and higher, as the copper saving resulting therefrom is overbalanced by the risk to personnel, the tendency for high voltage, D.C. shorts to hang on, commutation difficulties, and the difficulty of obtaining replacements from stock in case of breakdown.

D C.—Supply may be from:

a. Shaft driven generator
b. Exciter system
c. M.g. sets or converters
d. Turbo-generators (house generators)

If the auxiliary power requirements are in excess of about 500 kw., the D.C. shaft driven generator on the main turbine shaft running 1800 r.p.m. becomes somewhat special and 1800 r.p.m. commutation difficulties are not entirely negligible. A shaft driven generator large enough for auxiliary power and excitation has been installed on two 20,000 units in one of the utilities. I do not believe that this is desirable, as the excitation is of such importance that it should not be jeopardized by trouble on the auxiliary circuits.

Motor generator sets with induction motor drive do not give the possibility of power factor correction, but possess the advantage of being less sensitive to "bumps" on the A.C. circuit. To insure continuity of service, at least two sets should be installed if

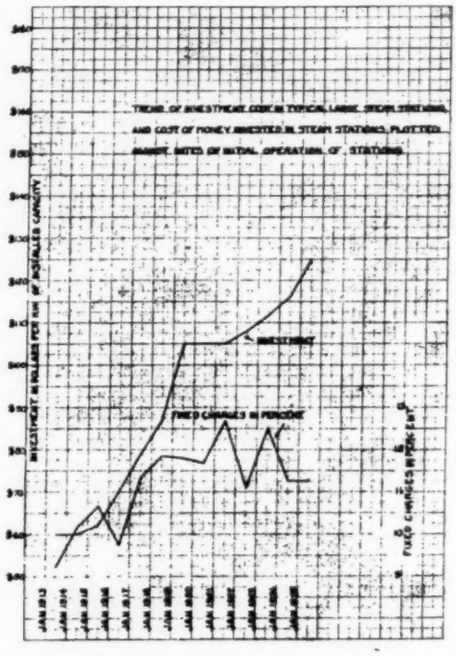

FIG. 5.

emergency service cannot be had from another source.

House generators are independent of the A.C., and I feel that for most installations they are the most reliable source of supply, although in this case also a second set or standby m.g. set running off of the main bus should be installed. Detroit's new 30,000 kw. station—Trenton Channel—using 4,000 kw. house generators, has been in service nearly two years, and, according to a recent article of Mr. Dow's, the D.C. has met their expectations and been entirely satisfactory.

With A.C. we have the choice of:

a. Shaft driven generators
b. House turbines
c. Transformers

Shaft generators are comparatively simple with A.C. as they involve no difficulties of design. The advantage of the steam economy of the main unit is very attractive, and the heat cycle can be laid out without having to fit into it the exhaust of a second machine. If the control is so arranged that essential auxiliaries are fed from the shaft auxiliary, we have

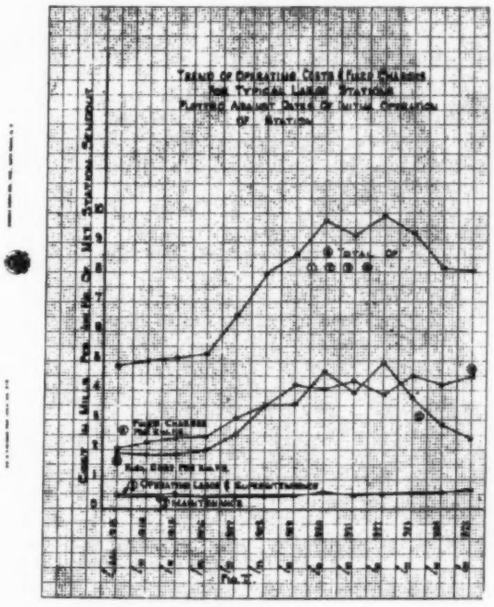

FIG. 6.

a pretty good guarantee of service that will be reliable and not affected by trouble on the main bus. As with D.C., an emergency supply should be provided.

Transformers for all auxiliaries are open to the objection that trouble on the main bus is reflected into the auxiliary circuits; but they provide a satisfactory supply for non-essential auxiliaries and as standby for the shaft driven generators. Transformers connected ahead of the generator oil switches afford a more reliable supply than if connected to the main bus.

With A.C. the engineer has the problem of the selection of voltage, and this is affected by so many considerations that it merits considerable study. A number of stations have gone to 2200 for the larger auxiliary motors, but then the saving in copper must be set up against the cost of higher voltage cables and insulation, switching equipment and the undesirability, from the standpoint of the operator, of having a dangerous voltage around the plant and on equipment which should have frequent attention. With 2300 for the larger motors, it is necessary to provide another supply for the smaller motors, as these are not standard for voltages above about 500. As it is advantageous to use equipment which is manufactured as a commercial standard, 440 has been used in a number of installations. In connection with the design of a pulverized fuel station which has now been in service about 18 months, a number of studies were made of the relative costs of 2300 and 440 volts for auxiliaries. As this station operates at 60 cycles, costs on 60 cycle equipment were obtained from the manufacturers. For squirrel cage motors, operating at 900 r.p.m., it is interesting to note that the cost curves for the two voltages plotted with motor costs as ordinates and h.p. as abscissa, crossed at 138 h.p. For 50 h.p. motors, the 2300 volt motor was 27½ per cent more expensive than the 440 volt. At 100 h.p., the curve showed the 2300 volt motor to be 10 per cent more expensive than the 440 volt. For wound rotor motors having the same synchronous speed as the squirrel cage motors, the cost—h.p. curves covering the range of 75 to 150 h.p. showed the 2300 volt motor to be more costly over the entire range. For 75 h.p., the 2300 volt motor price is approximately 6 per cent more than the 440 volt motor price. At 150 h.p., the 2300 volt motor was approximately 1¼ per cent higher in cost than the 440 volt. From the standpoint of the motor cost alone, it is thus evident that the 440 volt equipment shows an economic advantage only for the larger size motors. At 150 h.p., the squirrel cage motor at 2300 volts is approximately 4 per cent cheaper than the 440 volt motor. Our motor studies covered both 2200 and 440 volt motors with synchronous speeds from 575 to 1750 r.p.m. In practically every case, the 440 volt motor worked out to be cheaper.

Studies of the cost of distribution cable were also made and these showed that the cost per ft. is about equal at 100 h.p.; below this the cost advantage was in favor of 440 volts. Cable costs were based on 440 volt lead covered cable with 600 volt insulation, and 2300 volt lead covered cable with 4,000 volt insulation. Considering space requirements of the oil switches for 2300 volts, the cost of this equipment,

MAIN AUXILIARY CHARACTERISTICS OF CENTRAL GENERATING STATIONS.

Year of Initial Operation	Auxiliary Voltage: High (440-2300-4600-6600 etc.)	Medium (220-440-550 etc.)	Low (110-220 etc.)	Boiler Feed Pump Drive: Turbine	Turbine Motor	Motor	Circulating Pump Drive: Turbine	Turbine Motor	Motor
Other Years	0	1	2	2	1	0	3	0	0
1911	2	2	0	2	2	0	1	2	1
1912	0	1	0	1	0	0	0	1	0
1913	0	3	0	0	3	0	1	2	0
1914	0	1	0	0	1	0	0	0	1
1915	0	2	2	2	2	0	1	2	1
1916	1	1	0	1	1	0	1	1	0
1917	0	2	0	1	1	0	0	1	1
1918	1	3	0	2	2	0	0	2	2
1919	2	5	0	4	2	0	1	3	2
1920	3	0	1	3	3	0	2	2	2
1921	2	3	0	3	2	0	0	3	2
1922	2	0	1	0	3	0	0	1	2
1923	6	3	0	4	3	0	0	3	6
1924	12	3	0	6	8	2	0	2	12
1925	8	5	0	0	11	2	0	2	11
1926	6	0	0	1	4	1	1	1	4
1927	1	1	0	0	2	0	0	0	2

Note

1. Since practically every station has electrically driven auxiliaries and all use alternating current except for a very small portion of the auxiliaries such as stokers, it was assumed that all auxiliaries are driven using alternating current.

2. In cases where more than one voltage is used for the auxiliaries it was assumed that the larger auxiliaries, using the major portion of the auxiliary power, used the higher voltage.

3. The fans were almost without exception driven by motors.

4. Boiler feed pumps listed under Turbine and Motor Drive are usually motor driven with turbine driven stand-bys.

5. The numbers under each heading indicate the number of stations in that class for the stated year of initial operation.

FIG. 7.

cable costs and motor costs, our figures showed that for the station under consideration, the 440 volt system would be more economical; and, accordingly, this voltage was adopted.

In connection with the question of the best voltage for auxiliary circuits, there are a number of engineers who maintain that it is highly undesirable to use oil circuit breakers if we can substitute for them contactors or air break circuit breakers of the ordinary type. It is obvious that the circuit interrupting device should be of sufficient capacity to

handle a short circuit. In order to get a basis upon which to decide regarding the auxiliary system for the Consolidated Company's new station in Baltimore, a number of tests were carried out. Based on the reactance of the auxiliary transformers, and the reactance of the auxiliary generator, the problem was put up to the manufacturers to furnish 2000 ampere contactors or circuit breakers which under actual test would handle repeated short circuits of not less

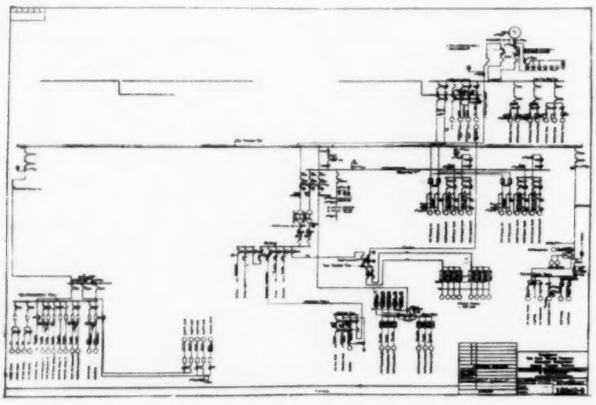

FIG. 8.

than 20,000 amperes at 440 v., 25 cycle. Briefly, the results of the contactor tests were that the standard contactors of the various manufacturers would not handle these currents, as after one or two operations the switches had a tendency to freeze. As these tests were witnessed by the manufacturers' representatives, several of the manufacturers made modifications to their equipment, after which the contactors stood as many as five shots with practically no damage. In fact, one of the contactors interrupted about seven shots of 25,000 amperes with only a trace of pitting. With slight modifications, several of the

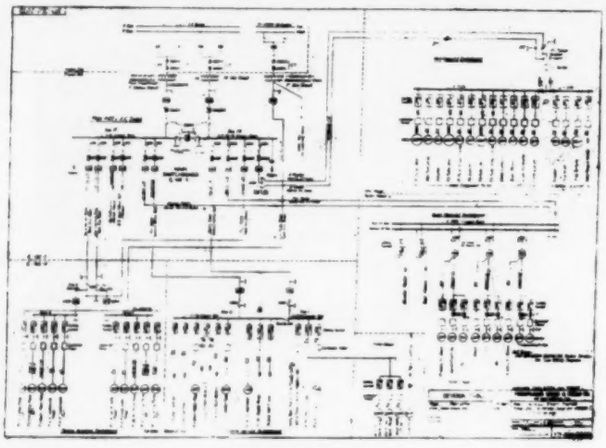

FIG. 9.

standard carbon circuit breakers handled about 20,000 amperes quite successfully. One feature that our engineers insisted upon was that the breakers be non-closeable on short circuit or trip free. Although the contactors handled the short circuits as well as the breakers, it was decided that the breakers were preferable to the contactors, as in case of failure of the holding coils in one of the contactors, this would drop out, which would not be the case with the circuit breaker provided with a trip. Aside from the space requirements of the oil circuit breaker, there is the maintenance problem. There is no way of telling whether a breaker has been properly serviced or whether it needs attention, without taking the tanks off, whereas with air break, pitting or burning of the contacts is readily discernible by inspection which can easily be made without in any way dismantling the equipment. Having in mind the ultimate capacity of the Consolidated's new station, and knowing the approximate maximum lengths of run and hp. of the auxiliaries, it was decided to use no oil breakers on the auxiliary circuits, all of the control circuits to be handled by carbon circuit breakers with selected control equipment for handling the individual motor circuits.

The one-line diagram of the auxiliary wiring is shown in Fig. 8. Auxiliaries were divided into two classes—essential and non-essential, the essential auxiliaries being those necessary for the uninterrupted operation of the turbine and boilers; the non-essential auxiliaries being those such as pulverizing machinery, coal handling plant, and other equipment,

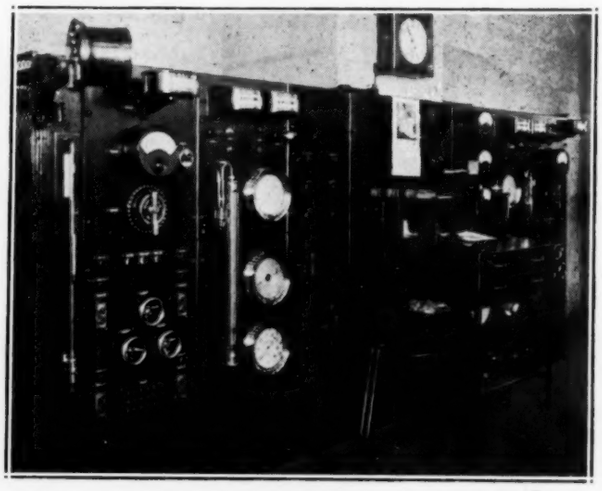

FIG. 10.

a temporary shutdown of which would not interfere with the operation of the main unit and boilers. The essential auxiliaries, as this diagram shows, are supplied with energy from the shaft driven alternator, the non-essentials from a bank of 3—1,000 kw. OISC transformers. The arrangement is such that in the event of failure of the shaft driven alternator, the load is automatically transferred to the transformer bank. All auxiliaries are 440 volt D.C. except the turbine room crane and the pulverized fuel feeder motors. These are supplied from motor generator sets, one running from the essential auxiliary bus, the other arranged to transfer automatically the load onto the transformer bank bus in the event of failure of the first motor generator set.

Fig. 9 shows the one-line wiring diagram for the Pennsylvania Water and Power Company's new Holtwood Station. Here conditions were somewhat different, and all electrically driven auxiliaries are supplied by transformers from the generator bus. The circulating pumps are provided with dual drive, the normal operation being with variable speed, 60 cycle motors. Tripping of one of these motor circuits automatically closes the switch on a 25-cycle

squirrel cage motor, which picks up the load on the circulator. In both the Baltimore and the Holtwood Stations, all auxiliaries under normal operation condition are electrically driven. In each of the stations, we have provided a steam driven boiler feed pump, for emergency service.

In connection with the general subject of auxiliary control, we are confronted with what might be termed two schools of thought. Some engineers prefer centralization of all control. This was done to a large extent at the Pennsylvania Water and Power Company's Holtwood Plant. A view of the

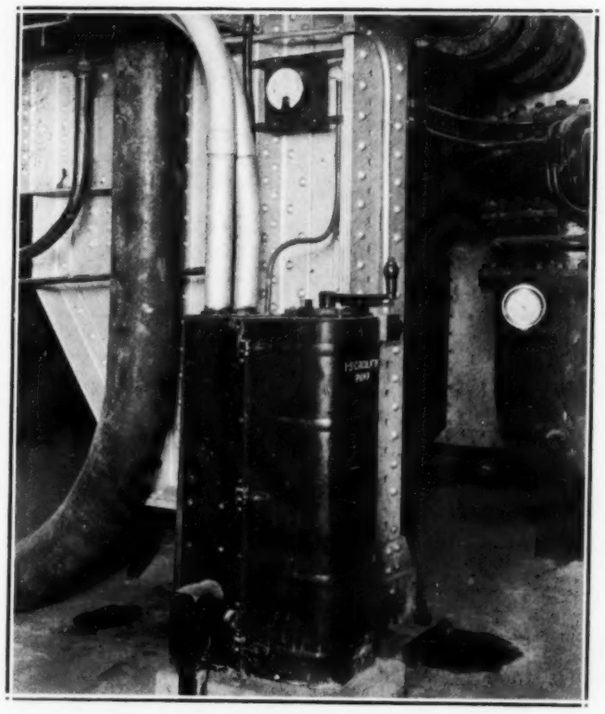

FIG. 11.

control board is shown by Fig. 10. Other engineers maintain that with the modern equipment, such as heaters, pumps, float valves, etc., which require continuous attention or which should at all times be under observation, it is unnecessary to go to the expense of a centralized control system, and, therefore, condensate pumps, circulators, drip pumps, and such equipment can better be handled manually by the operator at the location of the apparatus. Where the amount of auxiliary equipment which should be under continuous observation is such that a basement man is required, the expense and complication of the centralized control is unwarranted. In the Consolidated's new station, circulators, condensate drip pumps, and miscellaneous pumps are handled manually. Figure 11 shows one of the circulator controls. The controls for the smaller pumps, such as harbor water, have been grouped, and for these the equivalent of across the line starters are used. Figure 12 shows these controls, which are of within about 30 ft. of the apparatus; and in every case the operator can watch the equipment as he starts up. For the larger motors, hand-operated drums were used, and these drums were built to interrupt the primary circuit, which is desirable as it gives the operator or maintenance man absolute control and tends to greatly reduce the possibility of accident.

Where the possible economies of the modern station are to be realized to the fullest extent, it is not always practical to eliminate contactors or motor operated control. In connection with certain groups of equipment, this type of control has the important advantage that it makes it possible to so interlock the circuits that equipment will be started up in the proper sequence. The engineer is then confronted with the problem—Shall he use alternating or direct current on the holding coils of the contactor? At one station in the South where the coal handling equipment was controlled by A.C. magnet contactors, it is reported that a temporary dip in voltage frequently drops out all of the coaling equipment. If D.C. is adopted, we then have the case of both A.C. and D.C. on the same panel. The D.C. holding coil has the advantage that the inrush is lower, and the holding current is not affected by the presence of foreign particles between the armature and the magnet; that is, if the contactor does not seal, the holding coil is not "cooked out." Also, the direct current holding coil gives quieter operation, although in most power plants this should not be a determining factor. As a debit against the D.C. holding coils, we must charge the D.C. current and equipment necessary for supplying energy to these coils as the continuity of this service must also be assured. For the Gould Street Station in Baltimore, it was decided to use direct current for the holding coils, while the Holtwood Station has A.C. holding coils.

In industries such as the steel industry, and also in public utility plants, continuity of service is the prime requisite, and the controller manufacturer

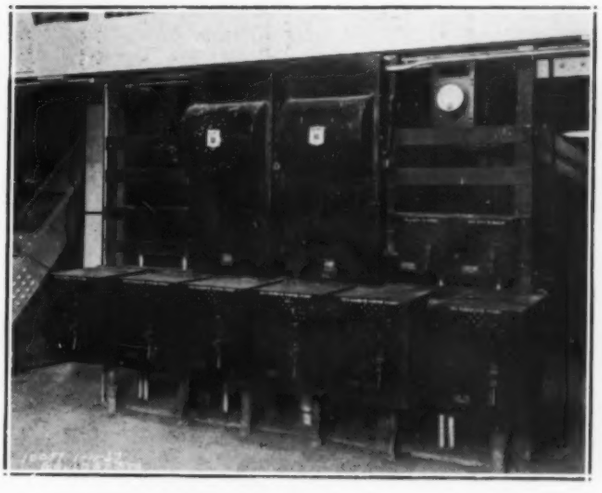

FIG. 12.

should realize this and build his equipment accordingly. In the case of auxiliaries of a large turbine, most utilities' operators would rather damage the motor or control than have the turbine go high pressure. Consequently, the usual type of overload as supplied by manufacturers for industrial purposes does not apply. If the motor starts to smoke, let it smoke. The basement man if he is on the job will make the necessary adjustments to relieve this condition, whereas the ordinary type of overload would kick out the motor. Ammeters with circuit breakers

set to trip at stalled current on the motor are a desirable arrangement. With the centralized control system using contactors, jam or screw down relays set to kick out at about the stalled current should be used. We have tested a number of the thermal overload relays, and I think I voice the opinion of a number of engineers in saying that most of these are too flimsy and cannot be depended upon to do the same thing twice. If the controller manufacturer will realize that the utility is willing to pay a reasonable sum for rugged equipment, and will design his equipment to be more husky and adapt it to handling by op-

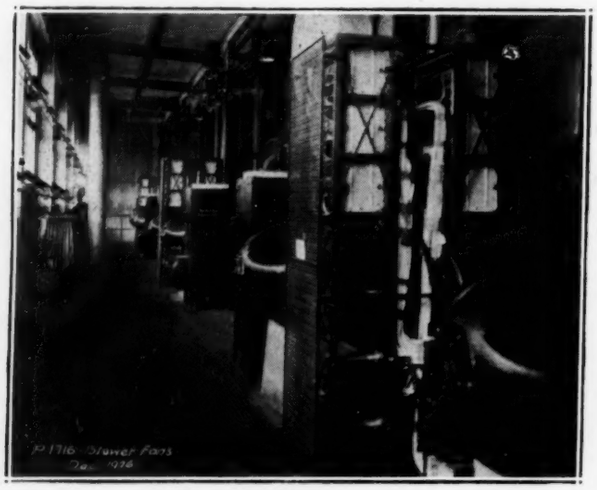

FIG. 13.

erators who are not instrument men or specially trained in handling electrical apparatus, I think many of our control problems would disappear.

For starting, we have time limit or current limit acceleration. With current limit, if anything happens to the equipment that maintains the current, the motor continues to soak or to operate under the higher current conditions. For most of our jobs, I think time limit is preferable, as after a definite time elapses the motor is thrown across the line and either picks up and begins to operate or the line contactor or breaker is thrown out. The dashpot relay has been widely used for time limiting acceleration, but recently one of the manufacturers has brought out a time relay working on a different principle. This relay is not affected by temperature as is the oil dashpot relay, but I think the equipment as a whole would be improved if the manufacturer would make it husky and more like a piece of power plant apparatus.

We have one other kick to raise with the controller manufacturers; that is, overheating of the contacts on control equipment which does not operate frequently, this overheating being caused by oxidation of the copper. It is now the practice in the Company with which the writer is associated to silver-coat all contacts which operate infrequently.

As steel mill engineers handling equipment which must be rugged and reliable, you have doubtless run up against the problem of powdering of the slate where contactors are mounted on slate panels. I know that some years ago, a similar condition was experienced in the Navy, where the shock of the gunfire fractured the slate; and the Navy adopted ebony asbestos, which seemed to solve its problem.

In a boiler house, the principal equipment to control is the fans, stoker motors or screw feeders, and boiler feed pumps. The A.C. current slip ring motor can be readily adapted to control of the boiler feed pumps as the speed range required is relatively small. For fans in modern stations where the rating range is very large, the speed range is very great, and the speed control problem is not so simple. With electric drive, the various methods of speed control that are open to us are:

1. Straight A.C. slip ring motors
2. Double winding A.C. motors, slip ring, and squirrel cage
3. Constant speed drive with mechanical speed change such as Reeves drive
4. Electro-hydraulic, such as the Hele-Shaw or Waterbury gear
5. Brush shifting A.C. motors
6. Variable frequency and voltage from a separate motor generator or turbo-generator.

The A.C. slip ring of the ordinary type is adapted to speed changes of down to about 50% of normal. The double winding motor gives us two synchronous

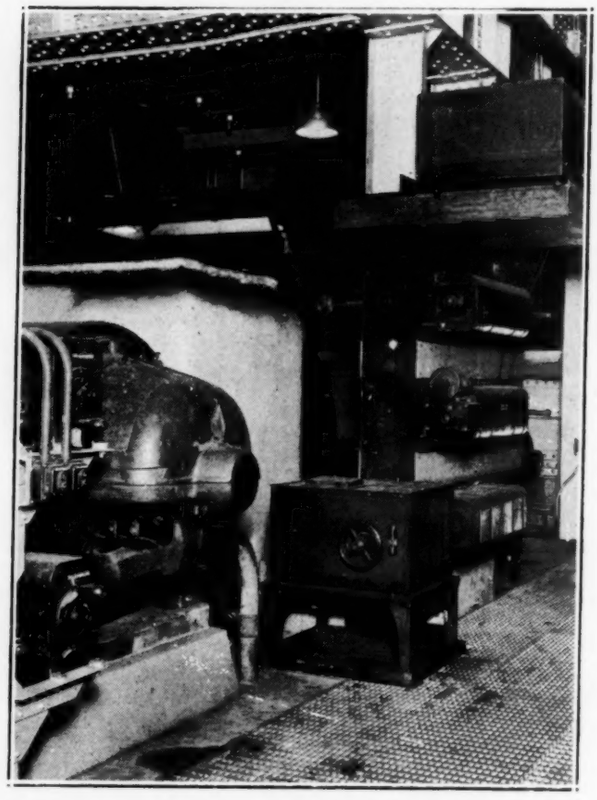

FIG. 14.

speeds, and if we use a double winding slip ring motor, intermediate speeds can readily be obtained The Hele-Shaw or Waterbury gear has been proposed. These equipments have been used by the American and British Navies and have been quite satisfactory, but have not as yet been applied commercially to any great extent. The equipment is rather expensive, and it is my understanding has not been built to handle more than 100 h.p. Variable frequency and voltage can be used, but this involves

considerable expense and separate sources of supply for each motor or group of motors, the speed of which is to be varied independently. The brush shifting motor has been used by a number of central stations, but this machine is more expensive than the standard motor and involves a commutator and a multiplicity of brushes, these features being particularly undesirable in powdered coal plants. The most efficient form of speed control, if we do not desire more than a 4/1 range, is with the D.C. motor, using field control. A greater range than this can be obtained by a combination of field and armature control such as has been adopted by the New York Edison Company on the powdered coal feeders of their new East River Station. The majority of the later central stations have automatic combustion control, and the several systems of control that have proved most satisfactory require a large number of speed points. This is readily obtainable with D.C., or by means of a suitable valve in the case of turbine drive; but the problem is not so simple with alternating current motors. Fig. 13 is a photograph of the speed control drums at the Pennsylvania Water and Power Company's Holtwood Plant. On these drums we have provided thirty points of speed control. For the Baltimore Plant double winding motors were installed, the forced draft fan motor rating being 30 and 200 h.p., and the induced draft fan 85 and 550 h.p. Fig. 14 shows the motor operated drums as installed at the Baltimore Plant. By the use of these drums, we were able to eliminate all contactors. On both jobs handles are provided for manual operation in the event of failure of the combustion control drive, and mechanical interlocks insure the proper sequence of operation.

DISCUSSION

S. S. Wales*: I have had the pleasure, the last month or two, of visiting quite a few of the sections, and wherever I go I find considerable interest in the objects of the society. Perhaps we sometimes make loyalty to a society solely our aim, and lose sight of its objects. I believe in all of our sections we are giving a great deal of attention to the objects of the society which is the interchange of ideas and methods of accomplishing electrical work and which is of the greatest importance to all of us. However, we are not confining ourselves strictly to electrical subjects—tonight we are talking about boilers. We cannot divorce the steam turbine from the steam boiler for they are pretty closely tied together. In Chicago we put on a paper on turbo-blowers for blast furnaces and had a bigger meeting than we have had for some time.

While of course our interests, we might say, are purely electrical, still conditions are changing and the electrical man must become familiar with the other phases as well.

Take, for example, one of our large plants one-half of which in the last two years we have completely electrified. The steam engine is pretty nearly out of the plant. The boiler plant is concentrated close to the power station, so that the electrical department is tending to a point where it may have to assume a large portion of the mechanical upkeep. We have in most cases assumed the care of the steam turbines, and may eventually go as far back as the boilers. So I am very much interested in that new branching out for the electrical man.

With regard to the interchange of information, I suppose you all know we have widened the scope of the paper in the last year. Mr. Kelly is now very glad to get articles of interest for publication that have not been subject to discussion in the sections. It is not necessary that a paper should have been read before a section and become a part of the proceedings in order to get into our paper.

Another development which I have noticed is that a great many of our mechanical men in the mills, master mechanics, chief engineers, etc., are asking for either admission to the society, or arranging to get our publications. They find that our files contain probably more subjects of value to the mill man than any other society in the country. As there is no other organization that devotes so much time to our particular branch than the AI&SEE, so in traveling around I find the job we are all trying to do in the various sections and in our national organization something well worth doing.

Of course we all realize that the most important man in a section and the most important man in the national organization, is the permanent secretary. Officers come, and officers go, but we have these permanent centers—the local secretary and the national secretary, and I think we should all of us give a vote of thanks, all the support we can, to our secretaries. The more I see of the good, conscientious work our secretaries are doing, the more I appreciate that the strength of our organization is located at that particular point.

A. J. Standing*: I want to congratulate Mr. Leilach on his exceedingly interesting paper. I think there is probably no phase of the problem he failed to touch upon. Some of the most interesting points in Mr. Leilich's paper were the curves showing the tendency towards reduction in b.t.u.'s per k.w. hour, and his reason as to the advantages to be gained, and just where the line of demarcation would come between the desirability of striving to go lower and the penalty you pay for it.

One thing that occurred to my mind was that Mr. Leilach stated the stockholders were interested in the returns and not so much in the method by which those returns were secured. In places where a plant site becomes a very appreciable item, and the ability to expand a plant is not there, then it becomes much more important that the existing possibilities be utilized to the maximum.

Now by plant sites, you not only refer to the first cost of the site, but to the taxes, and the necessary running expenses of such a plant on that site. Then I think you could afford to spend more money for the auxiliary equipment and the perfecting of it in order to maintain the maximum possible b.t.u.'s per k.w hour.

His reference to the economic situation was very interesting. It is a phase I think sometimes we do not get in close enough touch with, because in steel mill practice our problem is not quite as directly an economical one as it is in the public service operation. The types of drives are very interesting. There were some interesting comments made regarding the overloading feature, as to when it is ad-

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*Supt. Elec. Dept., Bethlehem Steel Co., Bethlehem, Pa.

visable to protect the motor, and when it is advisable to let the motor take the overload in order to protect the service. Where continuity of service is required it would be advisable to sacrifice the motor in order to maintain operation.

One other question in my mind is the question of auxiliary voltages. My personal feeling is in favor of what might be called low voltages. I do not like to see anything above 220-230 volts used in and around a steel mill. To a certain extent our equipment is a little more accessible to men who are not operators, although the tendency in steel plants is to isolate control and control houses, leaving the masters in the hands of the operators. It is a matter of opinion; but as I say, I personally do not like to see much over 220 volts. Then you have the one extreme or the other, it is either high tension or low tension with no intermediate voltage, betwixt and between, as it is almost impossible to say just where a fatal voltage begins or ends.

Taking Mr. Leilich's paper as a whole, I think he is to be congratulated. It contains an immense amount of data which should be read carefully and we will get a great deal out of it when this paper is printed.

C. R. Kemp*: Mr. Leilich has presented a most interesting discussion on the merits of distribution voltages for powerhouse auxiliaries and covers the ground in a very thorough manner.

In laying out our first station, we went through practically the same investigation that Mr. Leilach did but we decided on 2300 volts instead of 440. After thinking the matter over, we came to the conclusion that possibly we had not been entirely fair with the 440 volts and decided to try this out on our next station. Anticipating the contact trouble mentioned by Mr. Leilach, we called for much heavier carrying capacity on the contacts than the standard rating and had no trouble whatever with the contactors which we have. We have, however, as Mr. Leilich has mentioned, had trouble with the operating coils, allowing the contactors to open, due to low voltage. This possibility was considered at the time of design but the station in which this equipment was installed was designed and constructed in something like eleven months so that we had very little chance to do any shopping around for equipment. In fact, about all we could do with this station was to throw it together as fast as we could. The manufacturer who could supply the kind of contacts we wanted refused absolutely to consider the D.C. operating coils, in view of the shipment required. Since the trouble developed with these contactors, we have requested the manufacturer to furnish D.C. operating coils but, owing to the design of the contactors, it was impossible to apply the D.C. coil to the present contactor so that, if we desired to make the change, the only thing to do was to purchase new contactors.

I believe Mr. Leilich is inclined to underrate the liability of powdered fuel explosion. We had in the South Carolina Plant, shortly after we started operation, a number of explosions in the fire boxes, due to failure of the air supply. On failure of the air supply, the burner went out and, immediately on reestablishing the air pressure, the powdered coal ignited by the heat of the fire boxes exploded and blew the doors open. In several cases, some of the operators narrowly escaped injury, due to emission of flame when the fire doors opened.

As far as 2300 volt motors and switches are concerned, we have had no trouble with them. The maintenance of 2300 volt oil circuit breakers is quite a simple matter. I think our largest motor is around 350 H.P. We are using 300 or 400 ampere oil switches and have had no trouble from oil switch contacts. As to whether 440 volts is safe, I do not know. I do not think that 440 volts is much safer than 550 and, as Mr. Leilach has pointed out that 550 volts is undesirable in a plant, I question whether 440 volts is any better than 550 volts. Frankly, I do not see the difference when it comes to personal injury.

Concerning fuel feeders we have reached the conclusion that D.C. is the only successful method of handling wide ranges of speed control required on the fuel feeders. We tried out the B.T.A. variable speed motor but found on the wide range of speed control required that the horsepower of the motor dropped off so rapidly on the lower speed that it required a motor with a normal rating of about 20 H.P. to carry the load at the low speeds while 7½ H.P. was ample for the high speeds. This expensive motor was considered prohibitive so we installed two motor generator sets to supply D.C. for the fuel feeders. We did not consider using variable speed motors on the induced draft fans although we did install temporarily a number of variable speed motors on these fans but these gave trouble, due to extremely dirty conditions of the boiler room at that time. Due to the ash and other products of combustion settling on the rotor windings, slip ring and brush riggings, we had a number of short circuits which convinced us that the squirrel cage motor was preferable, if its use were possible.

We found it necessary on the fuel feeder system to put on some system of air control to prevent the fire box explosions. This air control is designed to automatically stop all fuel feeders in case the air pressure goes off.

In conclusion, I think that we owe Mr. Leilich a vote of thanks for the very able manner in which he has covered the question of voltages for powerhouse auxiliaries.

F. T. Leilich*: I would like to correct the interpretation of Mr. Kemp in regard to pulverized fuel. You were speaking about trouble in your furnace. I agree with you in regard to explosions of pulverized fuel. I think if we keep our pulverizing plant and equipment clean, we will greatly reduce the danger of explosions outside of the furnaces. Personally, I think explosion doors of the type we have been putting on our furnaces are of practically no value. We used explosion doors, and an appreciable quantity of ash seeped out every hour, so much that we could not keep the place clean. In order to keep the doors tight, the boiler manufacturer hung on these doors weights weighing about eighty pounds. We left the explosion doors off of our last job.

On the Baltimore job we are providing for the case of failure of the induced draft fans. We will

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*Engrg. Dept., Consolidated Gas Electric Light and Power Company of Baltimore, Baltimore, Md.

automatically trip out the forced draft fans in case of stoppage of the forced draft fans. I think we will put in relays or other devices so that in the event the feeders are all running at top speed, these will be slowed down by short-circuiting a part or all of the feed motor field resistances. There should be some form of tie or interlock between primary air and fuel aspirators. Perhaps some one will tell us where we can get a good automatic control valve. Should we succeed in obtaining that, in case the air goes off we can automatically turn on the steam or air.

C. R. Kemp: When I mentioned the air pressure relay, I had reference to the primary air which places the pulverized coal in the fire box, and we agree with you that we have not been able to find a valve that will do the trick. If we do, and it works, we will tell you how we did it.

F. T. Leilich: You are all familiar with Bailey's edgewise meters. We considered adding a mercoid so that in the event pressure falls below a certain point, the mercoid will operate an electrically controlled valve or sound an alarm.

F. O. Schnure*: I would like to ask Mr. Kemp which he considers the most economical—a squirrel cage motor with damper or a slip ring motor?

C. R. Kemp: We did not consider them at all. I do not think there is very much difference between them. In the one place, you waste energy in secondary resistance; and in the other place, you waste it in blocking off the air.

F. T. Leilich: Mr. Dodge of the General Electric Company has a rather interesting paper in the June, 1926, issue of the General Electric Review. He presented curves showing the input to motors of different types when used for fan drive. The squirrel cage motor with the damper control was considerably more wasteful of power. We have asked the control manufacturers for data on the multiple winding or double speed squirrel cage motor. At a slight increase in operating costs we may save enough in investment costs and simplicity to warrant giving the arrangement careful consideration.

D. M. Petty†: I feel we have all gotten a great deal out of Mr. Leilich's paper for, while it did not cover a purely electrical subject, it did show how the desired results were obtained electrically.

Safety First is our motto around Steel Plants, therefore in spite of the slight excess cost of 220 over 440 volts, I would favor eliminating all 440 and confirming auxiliaries driven by A.C. motors to either 220 or 2300 volts. 440 volts is too frequently treated as a low voltage and where it is used with higher voltages, more fatal accidents occur on this than on the higher voltages.

Continuity of service means a lot to the Public Utilities, but a lot more to the Steel Mills. Dropping a 20,000 K.W. turbine off of a 200,000 K.W. system is not serious, but when it drops off of a 40,000 K.W. system some of the operating Departments must shut down without warning and this means cobbled mills or loss of hot steel in an Open Hearth Department if a heat is being poured.

The use of two speed secondary controlled motors on fans is a good proposition, but the 60 cycle man has the choice of many more speeds than the man who only has 25 cycles, so that an efficient drive is much easier to work out with 60 than 25 cycles power.

I feel we owe a great deal to Mr. Leilich for his excellent talk and since we are both Lehigh men he will understand why I speak my mind so freely, particularly when I do not agree with him in detail.

G. F. Eidel*: I have been very much interested in this paper, and I would like to ask Mr. Leilich a question as to the sequence of operation of these breakers. I understand that the success of them depends on rapid operation. Is that correct? I refer to the air circuit breakers. And whether you have any trouble of the feeder short-circuiting and the main breakers tripping out, or whether you employ special relays other than the ordinary tripping devices?

F. T. Leilich: We have on those circuit breakers nothing but an ordinary drum. If the motor starts to smoke, let her smoke; if the operator does not catch it, he don't catch it; if we get a real short the breakers trip.

G. F. Eidel: The average circuit breakers would only have an overloading device for tripping, wouldn't they? With a short in your feeder, and your transformer bank supplying 20,000 amperes into that short, will your main breaker trip out, or do you set that to take care of that short and your high voltage circuit breaker?

F. T. Leilich: They are supposed to trip out on the 440 first and then go back on the A.C. if that doesn't work.

G. F. Eidel: But in every case you feed a circuit breaker?

F. T. Leilich: That is supposed to come first.

G. F. Eidel. You don't use any other protective devices?

F. T. Leilich: We are trying out some protective device, but I do not know whether we will keep it or not; it depends upon how well it functions. That of course is supposed to open up when the motor has reached the danger point. It remains to be seen how well that will function.

Answering Mr. Petty's question, I did not mean to infer that 440 volts was safe. I suppose we have all got 440 or more. That is a sort of compromise, you might say, between 220 and 2200. The switchboard I showed you is not open to everybody. The men are not supposed to monkey with it. Consequently, I think it does conform to your safety ideas. People are supposed to keep away from it and have no business there. We had quite a kick from the manufacturers to get it that way. Now if a man goes to work on that pump or the motor, no matter what the man upstairs does the motor does not start.

D. M. Petty: My own personal opinion is, I would have to see a good many dollars in saving of copper wire before I would put in a live switchboard on 440 volts. I would be perfectly willing to use disconnecting switches.

F. T. Leilich: That is what we did use.

D. M. Petty: In other words you are treating 440 volts the same as you did 2200. I think 440

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volts kills more people because it is treated as low voltage.

F. T. Leilich: Enclose the case with wire guards around it.

D. M. Petty: The cost of the motor in the large size would probably go up some in 220 volts.

F. T. Leilich: As I recall the figures, our voltage from the bus ran up around twenty per cent, and I think it is now around eight per cent.

E. D. Sibley*: I have been greatly interested in this paper tonight, but the conclusions of the speaker are not in line with our practice.

I tried to anticipate what was going to be said here tonight and, on the train coming to the meeting, I made a list of five (5) of our power stations, totaling 240,000 kilowatts. Two and one-half of these stations use powdered fuel and are modern.

In these stations there is installed 18,575 HP in motors for driving the station auxiliaries. Seventy-one per cent (71%) of this capacity is driven by 2300 volts, six per cent (6%) by 440 volts, twenty-one per cent (21%) by 220 volts and two per cent (2%) by direct current. The largest motor we have is 375 HP, driving a boiler feed pump.

In a small town it may be economical to supply the 2300 volt feeders from the power station and, while engineers will not agree that it is good practice to supply communities from the same bus as that supplying the station auxiliaries, it has been our experience in Reading, Easton and Binghamton, where this has been the practice for years, that no trouble has been experienced.

Mr. R. F. Gale†: This paper covers boiler house plants larger than generally in use in industrial plants, but the speaker settled one question that I had figured several different ways, and his figure was practically the same as I found. The dividing line horsepower—low voltage vs. high voltage—boiler house motors, particularly the fans. The size we figured was about 100 HP. The sizes mentioned, 138 and 150 HP given, it is quite evident were very carefully figured out, and am pleased to learn that they confirm my results.

My experience with powdered coal fired boilers (of which we have several) brought out similar troubles as mentioned, but we found that a constant head of powdered coal on the mechanism or screw is vitally necessary to give good control of the fire box, and the steam pressure. Should the supply be a little bit intermittent, even so little that the naked eye could not notice, serious difficulty arises and steam pressure cannot be maintained.

Powdered coal sometimes will run through the screw like water, even though the screw is ten feet long and stationary. If there is arching or a cavity in the overhead bunkers, 500 or 600 pounds falling at once, more coal comes through than is wanted, and flares occur. Sometimes to the extent of blowing out brick work. Much effort is being made to insure a uniform supply.

N. E. Funk‡: I was very much interested in the paper tonight, because the speaker thought the same as I do about many things.

You know quite frequently you have heard engineering referred to as an "exact science." That means that every fellow does exactly as he pleases, and I think that is probably one reason why there is such a tremendous difference in the way the same thing is done by different people. Sometimes we are a lot of sheep and follow a fellow that has had a little more "gimp" than we, so that because a particular way of doing a thing has been copied does not always mean it is right.

I can speak on both sides of the fence so far as the use of 440 and 2300 volts is concerned. We started putting in all our steam plant auxiliaries at 2300 volts in 1918. We are putting in all the Conowingo auxiliaries at 440 volts. There is a very good reason for the higher voltage that is used in the steam generating plants. The distances are fairly great between the source of supply and the individual auxiliaries, and a tremendous amount of copper would be used if at the lower voltage. The difference at Conowingo is that the essential auxiliaries for each unit are driven from an auxiliary generator on each unit. On the upper end of the shaft of the main generator is a small house generator or auxiliary generator. From this are driven the oil pumps for the governor, the exciter and the fan for drawing air through the generator. A higher voltage—2300—could not be used on account of the small size of the oil pump motors. These motors are essential motors and must be on a source of power that is not subject to disturbance. The fan motor is not so very large. It could, however, have been made a 2300 volt motor. You might say in this particular case that one of the reasons we went from our practice of shaft end exciters was because a shaft end exciter at eighty-two r.p.m was out of the question. We threw the shaft end exciter out and put a house generator on in its place. The difference in the cast of the motors and the difference in the cost of the interrupting equipment made the financial setup for 440 volts very much more favorable than for 2300 volts. All the motors are started by throwing them directly on the line. The air circuit breakers are arranged to trip out from balanced relays. This is not new since we have used balanced relays on large generators and their auxiliaries for some time. This type relay gets the faulty apparatus off quicker than any other type, and is very simple. The solenoid operated 440 volt breakers are all placed on one board for each unit, that is totally enclosed with a locked screen so that the operator cannot get into it.

In all but the oldest of our steam stations we have shaft end exciters, and in the latest one a transformer directly connected to the main generator leads ahead of the oil switch. The reasoning is something like this: The record of transformers, so far as reliability is concerned, is the best of any apparatus we know of. The small alternator does not have as good a record. Therefore, when you attach the house alternator to the shaft of the main unit you are really decreasing its reliability. The transformer does not do this.

All the essential auxiliaries for that turbine are operated from this transformer. The circulating pumps, condensate pumps and the air pumps are all motor driven, while the boiler feed pumps are partially motor and partially steam driven. All motors are started by closing a switch. They have nothing

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else in the circuit. The switch is opened by a balanced relay in case of a motor fault. It will not open on overload.

All the boiler house auxiliaries are taken off the main bus, if a main bus fault occurs these motors should shut down.

The turbine has two sets of relays, a balanced relay which will open the main switch of the turbine and take off the field. This relay will only open, however, in case of a fault in the turbine. There are also C Z relays on the turbine. If the voltage goes down low they will open at a low current value. If the voltage is high, a very high current is required to operate the relays, and it takes them much longer to open. If the voltage is normal the relay will never operate. These relays were arranged to open the main switch of the turbine only. The outfit has functioned properly. I do not think there is any real basic defect in taking the essential auxiliaries off the turbine itself as long as care is used in the detail design.

To obtain an equal amount of reliability in the first station with motor driven auxiliaries that we built, we put in a circulating pump with a 2300 volt motor on one end, and a geared turbine drive on the other, so that if the electric power went off the steam turbine would pick up the pump load.

Another thing I have in mind is A.C. contactor coils. We have them on 52 boilers. We put them in in 1918, and have kept on putting them in. We have not had any trouble with the A.C. contactors on account of the way we use them. In case a feeder to a boiler goes off, the contactors on the auxiliaries of that boiler will trip, or in case the whole station supply should shut down, all the contactors will open and shut down the motors. As soon as service is restored all motors will come up to the speed at which they were operating when the interruption occurred. You can only get that control with A.C. coils on an A.C. supply, unless you put on a lot of little relays.

We had some grief with the A.C. coils when first put in—over-heating and burning out, because they would go on the line and maybe run for a week, and the current would be on them all the time. They were designed for intermittent industrial purposes. It was a question of the improper application of a perfectly good device.

D. M. Petty: Mr. Leilich made one statement I may have misunderstood. The general trend was he used an induction motor driven set because they would hang on to the line through a bump in the A.C. voltage better than a synchronous motor driven set. I have not any definite experience on that line, except my understanding is that a synchronous motor driven set hangs on as well as an induction set. The only advantage I can see in an induction motor set is that it would start up again if voltage went off and then came back on again. The other motor will not.

F. O. Schnure: I might say in that connection that we have an induction driven exciter set and we have to plug the last contact in order to keep it on the line in service.

Installation and Operation of Air Compressor Plants for Avoidance of Explosions

By W. GREENWOOD*

FROM long experience I have become convinced that rules to govern employees within industries in the performance of their work, which are issued in brief form and though they are mandatory, do not get read more than once or at most but a very limited number of times before the book is laid aside and in time is forgotten. It is a remarkable and strange fact that very frequently when an accident occurs the victim or responsible party will deny knowledge of a rule which, if followed, would have avoided the accident, and we are reasonably sure an opportunity was afforded for reading the rule. I have noticed too, that some department heads and their assistants have not taken the trouble they should take to thoroughly acquaint themselves with the safety and operating rules that affect their employment, and too, often they have not even read what was put before them.

There is an exception to the foregoing statement in the case of railroad operatives. All railroad managers follow the system of penalizing employees for neglect to comply with rules, and ignorance of them furnishes no excuse. In fact railroads could not be operated with any degree of success if their rules were not complied with. A full understanding of the rules is the first and most important requisite demanded of an employee before he enters on his duties.

One of the most important movements that can be made within any corporation would be, to conduct a campaign for enforcing employees to acquire a full knowledge of their operating and safety rules.

Another idea that I have entertained for a long time is, special rules that are issued for installation and operation of particular kinds of equipment, like engine stops, air compressors, coal pulverizing plants, etc., should be accompanied by a brief general treatise that would be educational in its effect. When the general principles involved are understood the importance of the rules are better understood and there is less likelihood of forgetting to apply them.

Of all the discussions that have been printed concerning air compressor explosions which have been called to my attention and of all I have listened to, no two agree in every particular. My efforts in compiling information have been directed toward

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reconciling the differences of opinion and proving opinions that seem to be plausible. This work has been aided by personal investigation of occurrences as well as reports of investigations; these usually revealed that what occurred necessarily must have followed natural lines of sequence which are common knowledge. In checking up my own conclusions with those expressed by others I find mine agree with a majority of those expressed, and usually those who expressed the most acceptable opinions had given considerable thought to the subject and too, they were supplied with best opportunities for investigating.

Without going extensively into details, the conditions that are responsible for explosions within air receivers and piping are herein described. When some of the most important methods of installation have been complied with, that apply to avoidance of pockets for gas to linger in and proper control devices for unloading pumps and excess pressure, cooling, etc, there never has been such an explosion. With the installation of equipment in accordance with all known proper methods for safe operation, including appliances and methods for control, explosions will be impossible.

Investigations made during a long interval of time point to the fact that explosions within piping from air compressors, and within receivers, are due primarily to the oil used for lubricating air cylinders. While theories advanced by different persons in regard to sequential order of the steps involved in the gasifying process do not concur, all agree that gas occurs from decomposition of the oil, and that it is ignited in some manner. The inference that heat, which must cause the ignition, is generated within the compressor cylinders, cannot be denied. While oil can be wastefully used its economical use within the lowest actual requirements does not entirely relieve the situation, and neither does the quality of the oil as regards high flash test. Heat will decompose heavy oil as well as the light.

While we have said economical use of oil and using oil of high flash test does not entirely relieve the situation, we must admit they contribute very materially to the liability of producing gas that can be ignited. The grade of oil that should be used is easily determined; controlling the quantity is another matter, not alone of uniform control but of judgment. Using too much is wasteful, not enough is ruinous to equipment. Since maintaining the proper medium entails doubt, naturally the leaning is toward excess be it much or little. However, when all interests are considered, positive control should be maintained as can be done by a forced feed system.

It has been found that accumulations consisting of carbon residue, from decomposed oil, and particles of dirt or material such as float in the air, which are bonded by the residium, will contribute toward formation of the vapors that are the most easily ignited and toward lowering the ignition temperature. When an explosion or series of explosions occur, which are not of a serious nature, this residium and dirt formation is hardened, then successive explosions will tend to keep it hot. Investigation has shown that gas cannot be produced from oil that is formed by precipitation of oil vapors, such as is found within receivers or piping, without exposure to heat for a considerable length of time. This goes to show that decomposition of oil to produce dangerous gases primarily occurs in the air cylinders, and further decomposition of oil vapor can occur from contact with the hard and hot deposits within the system. This condition can be remedied very much by the use of air filters which, to a large extent, are a necessity for protecting the equipment from the abrasive effect of dust.

All the various forms of hydrocarbon, that can be produced from oil, must remain within the air system except as it may escape where the air is employed; if though, when gas is formed, the construction and operation of the equipment will permit it to stratify in accordance with its varying degrees of gravity, or separate from the air when pockets are provided that it can linger in, as is the case with many installations, it is liable to ignite or explode, the violence of the explosion being governed by inherent conditions such as effect thoroughness of mixture and instantaneous ignition of the entire mass. The force of explosions that can occur will vary in degree and many of them will not exert a pressure that cannot be relieved by the safety valves, but these never come into action until after the explosions occur. In some cases evidence goes to show that where the explosion burst the receiver and wrecked the plant, the pressure exerted exceeded 700 pounds. Such pressure could not have been prevented by a considerable number of safety valves as they ordinarily are constructed. The only purpose of relief valves is to prevent rise of air pressure above predetermined limits, and since they have no value for preventing explosions, they should not be considered safety valves in the sense that they will prevent a dangerous rise of pressure which may occur from ignition of gas.

It must not be assumed that the gas which accumulates in pockets will ignite spontaneously or from a shock. While it may be possible for the physical properties of the gas, generated from oil within the system of an air compressor plant, to undergo such change of structure as to render it liable to ignite spontaneously or from a shock, this is extremely improbable. The gas must be in contact with a high degree of heat to ignite and given the two factors, gas and air of high temperature, ignition must occur if they are brought in contact. Air always leaves the last stage of a compressor with its constituent parts unchanged; under ordinary conditions oil leaves in the form of vapor and carbon residue. Some temperature—more or less according to the efficiency of the compressor for cooling—remains in these parts after they leave the compressor. With a damaged discharge valve in the cylinder of any stage of a compressor the temperature of air discharged from that stage will be much higher than it should be. It is because of impaired equipment, valves or pistons, that the temperature is raised. The rise often times is very rapid. Temperature of parts of equipment above 900 degrees F have been observed and above 1400 degrees has been reached. It cannot be said it is possible to avoid the occurrence of defects, but it is true defective equipment, aside from neglect to keep water circulating through the coolers, is entirely responsible for generating abnormal rise of temperature. Where further provision has been made for cooling, after the air has left the last stage of compression and before entering the receiver, by supplying an after cooler with extensive radiating surface exposed to the atmos-

phere, there is but little if any liability of an explosion within the receiver, but it cannot be said it is impossible for one to occur.

It would seem that many installations of air compressor plants have been made in accordance with ancient custom, without concern for its defects or for making improvement on it. Receivers usually are installed close to compressors. There is no good reason why they should not be installed far from the compressor, in the distribution system. This method permits of heat radiation while the air is traveling through the line. Receivers should be installed with the intake at the bottom and discharge connections and relief valves should be at the top of receiver. Custom seems to have decreed that pipe connections to receivers should be made with a view of providing pockets for vapors to linger in order that they may condense and settle to the bottom, but very volatile gas can also linger in them. Deposits of sludge—which is formed from vapors of oil and water along with some other matter—within the compressor and distributing lines, cannot be avoided, but there is a practical way for removing it. Usually where methods have been provided for unloading the compressor they are unfit for the requirement, and in comparison with later developments are obsolete. Retaining them is not justified by desire to avoid the necessary expenditure required for up to date equipment which will lower maintenance cost and give added security to life and property.

Following is a code of rules for safe installation and operation of air compressor plants, the rules in most instances being accompanied by notes containing suggestions or explanatory matter. Since there are so many different makes of compressors in use no specific recommendation can be made as to particular construction further than to recommend such changes, as may be suggested, that can be made without incurring an expense that would not be justified by the reduction of hazard that would be secured.

Unloading: Where unloading is done, to conserve power, it must be done by a method that will not increase the temperature of parts of the compressor or of air within the cylinder.

NOTE: Where operations are so continuous that it is preferable to continuously operate the compressor, sometimes in order to conserve power, the compressor is automatically unloaded by closing the intake or by circulating the air through the cylinders. In either case the temperature of parts of the compressor is raised very high and disastrous results may follow. A better method for unloading is to hold the intake valves open and permit air to enter and back out with the changes of piston stroke. An unloading device can be procured that will act as a control governor in that it will control at points on a graduated scale, ranging from a point slightly above maximum operating pressure to the full capacity of the compressor, without a change of driving speed.

Where electric motors are used for operating compressors such kind can be provided as will automatically stop and start under full load as requirements demand. To do this requires such excessive capacity and intricate construction that but little, if any, saving can be effected over smaller capacity and less intricate construction that would have insufficient torque to start under full load. If though such construction should be considered, and if a synchronous motor would not give sufficient starting torque, then a wound rotor induction motor should be supplied. If stopping and starting would occur very frequently it might be advisable to have some slip regulation. A.C. Current should be preferred where it is available. If D.C. Current is used the motor should be compound wound and of high starting torque. Possibly some new development in the construction of motors may bring out one that will overcome the objections herein mentioned concerning efficient and economical operation.

Everything considered, it is better where either steam or motor drive is used, to run continuously and do the unloading by a method that will not permit excessive heating of air.

Lubrication: High test specially prepared compressor lubricating oil should be used for lubricating compressor cylinders.

Packing for piston rods must be of such kind that oil used for lubricating piston rods cannot be sucked into the air cylinders.

Special provision should be made for preventing more oil than is actually necessary for lubrication from entering the air cylinders.

NOTE: The best method for securing proper lubrication of air cylinders, without admitting too much oil, is by use of mechanical force feed systems. Any gravity feed or feed forced by steam pressure will permit oil to enter the cylinder during a stop unless the feed is manually operated to close it. Prompt manual operation is too unreliable for placing dependence on it.

Removing Sludge: Accumulations of oil and water, commonly called sludge, that settles on inside of receivers and piping, should be removed from time to time as it may accumulate.

NOTE: Oil and water vapors along with carbon residue and particles of dirt, settle on the inside of piping and receivers until a considerable coating of "sludge" is formed. The oil contained in this "sludge" might, on having hot air come in contact with it, be gasified and the gas ignited. The accumulations of "sludge" can be removed by feeding a strong solution of lye water through the compressor and piping.

Receivers: Air receivers should have a factor of safety not less than 8. A higher factor is preferable. They should receive a hydro-static test 50% above working load before they are placed in service. They should set on masonry or other support that will keep them as free as possible from moisture or moist material that would cause oxidation, and they should set on end.

Drainage: A baffle should be provided in the discharge line from compressor, between it and the receiver, that will arrest oil and moisture. Baffle and receiver should be provided with means for discharging the oil and water that may collect within them.

Relief Valves: To prevent a rise of temperature above the intended working pressure a relief valve should be placed in the discharge from compressor, between it and the first shut-off valve. One or more relief valves, for a similar purpose,

should be installed directly on the receiver. They should be tested periodically to see that they are not sticking. They should be protected from freezing and, where they discharge through piping to outside of building, they should be provided with free drainage close to the valve.

NOTE: The capacity of relief valves should be large, as they sometimes can release the pressure occasioned by an explosion before it has attained its highest rise. These explosions may be progressive in their action, that is, combustion may start in slow burning vapor and travel through the higher grades of combustibility to the highest, during a time which, though brief, would be measurable, and the greatest severity would occur when the last and richest stage was reached.

Piping: Steel fittings should be used with the piping. The inlet to receiver should be through one end and the outlet through the other end. Preferably the inlet should be through the bottom head and the outlet through the top head. If one or the other should be through the bottom ring sheet the location should be only far enough from bottom to leave sufficient space for accumulation of oil and water.

NOTE: In some cases the receivers are piped so that the air does not enter at one point and leave at another, but the distributing line is a continuation of the discharge line from compressor. The entrance to receiver may be through one or the other head or it may be through one of the ring sheets. In any case this makes the receiver, which is only a storage or equalizing reservoir, a receptacle that might contain gas instead of air. A continuous flow should be maintained through the receiver and for that reason the inlet should be at one end and outlet at the other.

Cooling: Air coolers should be provided for each stage of compression, and there should be an air cooling system out doors beyond the final stage of compression.

NOTE: An after cooler can be satisfactorily provided in the following way: Headers of suitable dimensions can be connected in pairs by a large number of small pipes of suitable size, and all arranged so that air entering the first header passes out through the entire system into the receiver. This arrangement permits the atmosphere, to which it is exposed, to reduce the temperature of air within the piping.

Air Suction: Suction lines should be as short as conditions will permit, direct, drain downward from the compressor inlet, and the air should enter through an air filter. Preferably the air should be taken from outside the building where its temperature is low, where there are no pools of water or oil, and where there is no unusual dirt or moisture in the atmosphere.

Pressure Gauges: A pressure gauge should be installed at each stage of compression to indicate the pressure, and warn operators of sticking or leaky valves in the compressor.

Thermometers: A large scale indicating thermometer of the wall type, should be inserted in the discharge line in plain view, and it should be marked with a red mark at some point on the scale that will indicate temperature too much above normal. This will indicate probable derangement of equipment in time to remedy it before the temperature becomes dangerous.

Rules: The following requirements, briefly worded on a bronze tablet, should be attached to a cylinder of the air compressor in a conspicuous place:

Clean valves carefully with kerosene before starting, after long stops.

Keep valves free from gum and dirt.

See that cylinders and intake are clean.

Take air from cool and clean source.

Use smallest amount of oil possible.

Use high grade high flash compressor oil in cylders.

See that water jackets have free outlets and be sure water is circulating before starting compressor.

See that lock screws are holding seats tight on cylinder, and that copper gasket under seat is in good condition.

Lock screws should be adjusted whenever cover is removed.

Read carefully and follow printed instruction cards sent with compressors.

Iron and Steel Exposition

Syria Mosque, - Pittsburgh Pa.

June 13th to 18th, 1927

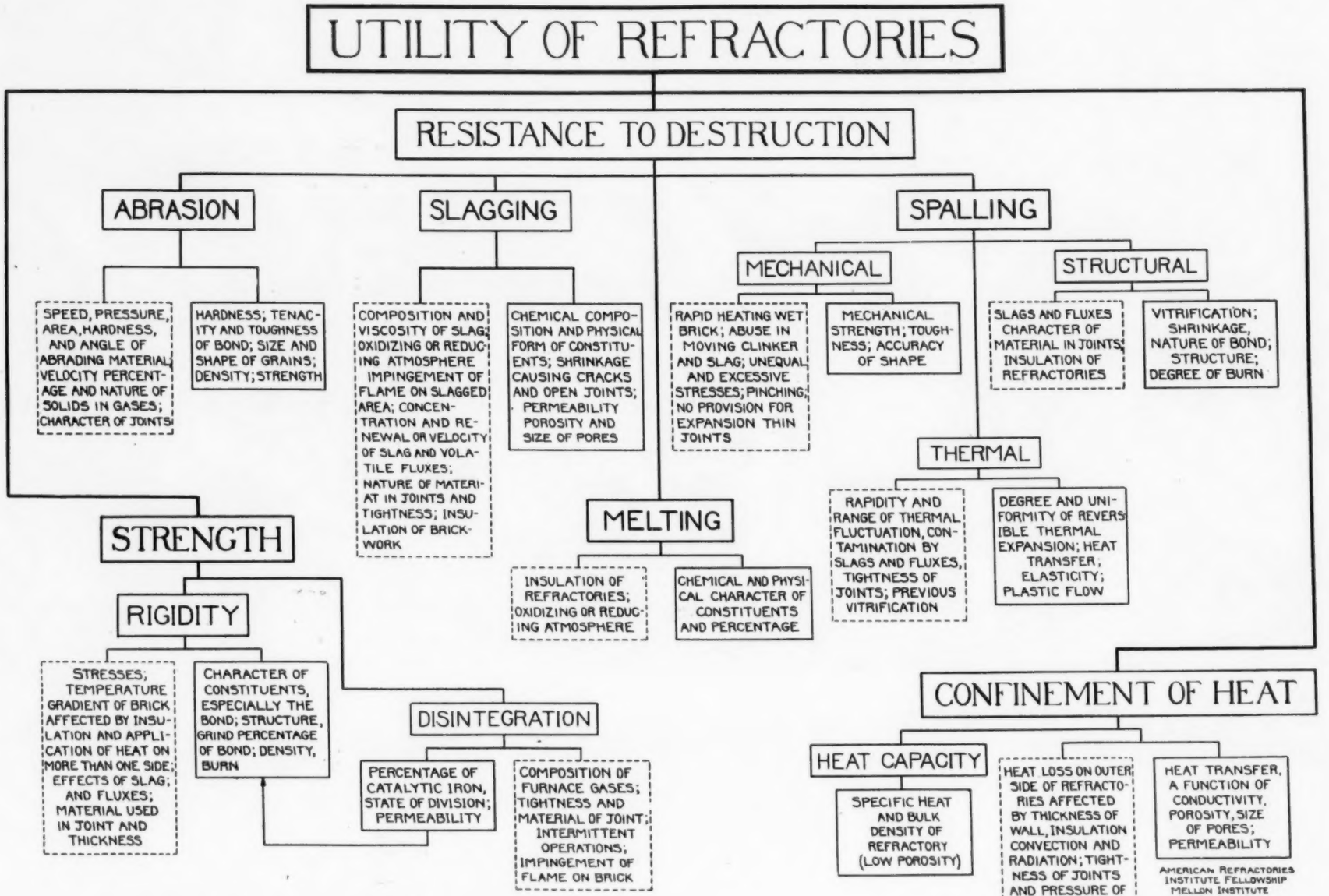
The June Number of the Iron & Steel Engineer will contain all the papers to be presented at the technical sessions:

Official Program
Items of Interest
Points of Interest
Convention Committees
District Committees
National Committees

In fact, the complete story of the Convention and Exposition will appear in this number. It will be mailed June 1st.

WATCH FOR YOUR COPY

Standardization Committee employing the first Commutating Pole Mill Type Motor built in accordance with specifications of the Association of Iron and Steel Electrical Engineers.


UTILITY OF REFRACTORIES
RESISTANCE TO DESTRUCTION
ABRASION
SLAGGING
SPALLING
SPEED, PRESSURE, AREA, HARDNESS, AND ANGLE OF ABRADING MATERIAL; VELOCITY PERCENTAGE AND NATURE OF SOLIDS IN GASES; CHARACTER OF JOINTS
HARDNESS; TENACITY AND TOUGHNESS OF BOND; SIZE AND SHAPE OF GRAINS; DENSITY; STRENGTH
COMPOSITION AND VISCOSITY OF SLAG; OXIDIZING OR REDUCING ATMOSPHERE IMPINGEMENT OF FLAME ON SLAGGED AREA; CONCENTRATION AND RENEWAL OR VELOCITY OF SLAG AND VOLATILE FLUXES; NATURE OF MATERIAT IN JOINTS AND TIGHTNESS; INSULATION OF BRICKWORK
CHEMICAL COMPOSITION AND PHYSICAL FORM OF CONSTITUENTS; SHRINKAGE CAUSING CRACKS AND OPEN JOINTS; PERMEABILITY POROSITY AND SIZE OF PORES
MECHANICAL
STRUCTURAL
RAPID HEATING WET BRICK; ABUSE IN MOVING CLINKER AND SLAG; UNEQUAL AND EXCESSIVE STRESSES; PINCHING; NO PROVISION FOR EXPANSION THIN JOINTS
MECHANICAL STRENGTH; TOUGHNESS; ACCURACY OF SHAPE
SLAGS AND FLUXES CHARACTER OF MATERIAL IN JOINTS; INSULATION OF REFRACTORIES
VITRIFICATION; SHRINKAGE, NATURE OF BOND; STRUCTURE; DEGREE OF BURN
THERMAL
RAPIDITY AND RANGE OF THERMAL FLUCTUATION, CONTAMINATION BY SLAGS AND FLUXES, TIGHTNESS OF JOINTS; PREVIOUS VITRIFICATION
DEGREE AND UNIFORMITY OF REVERSIBLE THERMAL EXPANSION; HEAT TRANSFER; ELASTICITY; PLASTIC FLOW
MELTING
INSULATION OF REFRACTORIES; OXIDIZING OR REDUCING ATMOSPHERE
CHEMICAL AND PHYSICAL CHARACTER OF CONSTITUENTS AND PERCENTAGE
STRENGTH
RIGIDITY
STRESSES; TEMPERATURE GRADIENT OF BRICK AFFECTED BY INSULATION AND APPLICATION OF HEAT ON MORE THAN ONE SIDE; EFFECTS OF SLAG; AND FLUXES; MATERIAL USED IN JOINT AND THICKNESS
CHARACTER OF CONSTITUENTS, ESPECIALLY THE BOND; STRUCTURE, GRIND PERCENTAGE OF BOND; DENSITY, BURN
DISINTEGRATION
PERCENTAGE OF CATALYTIC IRON, STATE OF DIVISION; PERMEABILITY
COMPOSITION OF FURNACE GASES; TIGHTNESS AND MATERIAL OF JOINT; INTERMITTENT OPERATIONS; IMPINGEMENT OF FLAME ON BRICK
CONFINEMENT OF HEAT
HEAT CAPACITY
SPECIFIC HEAT AND BULK DENSITY OF REFRACTORY (LOW POROSITY)
HEAT LOSS ON OUTER SIDE OF REFRACTORIES AFFECTED BY THICKNESS OF WALL, INSULATION CONVECTION AND RADIATION; TIGHTNESS OF JOINTS AND PRESSURE OF FURNACE GASSES
HEAT TRANSFER, A FUNCTION OF CONDUCTIVITY, POROSITY, SIZE OF PORES; PERMEABILITY
AMERICAN REFRACTORIES INSTITUTE FELLOWSHIP MELLON INSTITUTE PITTSBURGH PA. MARCH 1927

NOTE.- FACTORS ENCLOSED IN BROKEN BOXES REPRESENT CONDITIONS OF SERVICE WHILE THOSE IN SOLID BOXES REFER TO PROPERTIES OF REFRACTORIES.

End Points of Pyrometric Cones[1]

Temperature Conversion Tables

End Points of Pyrometric Cones[1]

(Heated in air at the rate of 150°C per hr.)

Cone No.	End Point °F	End Point °C
1	2120	1160
2	2129	1165
3	2138	1170
4	2174	1190
5	2201	1205
6	2246	1230
7	2282	1250
8	2300	1260
9	2345	1285
10	2381	1305
11	2417	1325
12	2435	1335
13	2462	1350
14	2552	1400
15	2615	1435
16	2669	1465
17	2687	1475
18	2714	1490
19	2768	1520
20	2786	1530
23	2876	1580
26	2903	1595
27	2921	1605
28	2939	1615
29	2984	1640
30	3002	1650
31	3056	1680
32	3092	1700
33	3173	1745
34	3200	1760
35	3245	1785
36	3290	1810
37	3308	1820
38	3335	1835
39	3389	1865*
40	3425	1885*
41	3578	1970*
42	3659	2015*

* In Arsem Furnace at 600°C per hr.

The temperatures in the above table will apply with fair approximation for the cones when heated in kilns where the gases are normally oxidizing and free from sulphur oxides.

[1] J. Am. Ceram. Soc., 9, (11), 701-743 (1926).

Temperature Conversion Tables

By Albert Sauveur

0 to 100			100 to 1000			1000 to 2000			2000 to 3000		
C.		F.	C.		F.	C.		F.	C.		F.
—17.8	**0**	32	38	**100**	212	538	**1000**	1832	1093	**2000**	3632
—17.2	**1**	33.8	43	**110**	230	543	**1010**	1850	1099	**2010**	3650
—16.7	**2**	35.6	49	**120**	248	549	**1020**	1868	1104	**2020**	3668
—16.1	**3**	37.4	54	**130**	266	554	**1030**	1886	1010	**2030**	3686
—15.6	**4**	39.2	60	**140**	284	560	**1040**	1904	1116	**2040**	3704
—15.0	**5**	41.0	66	**150**	302	566	**1050**	1922	1121	**2050**	3722
—14.4	**6**	42.8	71	**160**	320	571	**1060**	1940	1127	**2060**	3740
—13.9	**7**	44.6	77	**170**	338	577	**1070**	1958	1132	**2070**	3758
—13.3	**8**	46.4	82	**180**	356	582	**1080**	1976	1138	**2080**	3776
—12.8	**9**	48.2	88	**190**	374	588	**1090**	1994	1143	**2090**	3794
—12.2	**10**	50.0	93	**200**	392	593	**1100**	2012	1149	**2100**	3812
—11.7	**11**	51.8	99	**210**	410	599	**1110**	2030	1154	**2110**	3830
—11.1	**12**	53.6	100	**212**	413	604	**1120**	2048	1160	**2120**	3848
—10.6	**13**	55.4	104	**220**	428	610	**1130**	2066	1166	**2130**	3866
—10.0	**14**	57.2	110	**230**	446	616	**1140**	2084	1171	**2140**	3884
— 9.44	**15**	59.0	116	**240**	464	621	**1150**	2102	1177	**2150**	3902
— 8.89	**16**	60.8	121	**250**	482	627	**1160**	2120	1182	**2160**	3920
— 8.33	**17**	62.6	127	**260**	500	632	**1170**	2138	1188	**2170**	3938
— 7.78	**18**	64.4	132	**270**	518	638	**1180**	2156	1193	**2180**	3956
— 7.22	**19**	66.2	138	**280**	536	643	**1190**	2174	1199	**2190**	3974
— 6.67	**20**	68.0	143	**290**	554	649	**1200**	2192	1204	**2200**	3992
— 6.11	**21**	69.8	149	**300**	572	654	**1210**	2210	1210	**2210**	4010
— 5.56	**22**	71.6	154	**310**	590	660	**1220**	2228	1216	**2220**	4028
— 5.00	**23**	73.4	160	**320**	608	666	**1230**	2246	1221	**2230**	4046
— 4.44	**24**	75.2	166	**330**	626	671	**1240**	2264	1227	**2440**	4064
— 3.89	**25**	77.0	171	**340**	644	677	**1250**	2282	1232	**2250**	4082
— 3.33	**26**	78.8	177	350	662	682	**1260**	2300	1238	**2260**	4100
— 2.78	**27**	80.6	182	**360**	680	688	**1270**	2318	1243	**2270**	4118
— 2.22	**28**	82.4	188	**370**	698	693	**1280**	2336	1249	**2280**	4136
— 1.67	**29**	84.2	193	**380**	716	699	**1290**	2354	1254	**2290**	4154
— 1.11	**30**	86.0	199	**390**	734	704	**1300**	3272	1260	**2300**	4172
— 0.56	**31**	87.8	204	**400**	752	710	**1310**	2390	1266	**2310**	4190
0	**32**	89.6	210	**410**	770	716	**1320**	2408	1271	**2320**	4208
0.56	**33**	91.4	216	**420**	788	721	**1330**	2426	1277	**2330**	4226
1.11	**34**	93.2	221	**430**	806	727	**1340**	2444	1282	**2340**	4244
1.67	**35**	95.0	227	**440**	824	732	**1350**	2462	1288	**2350**	4262
2.22	**36**	96.8	232	**450**	842	738	**1360**	2480	1293	**2360**	4280
2.78	**37**	98.6	238	**460**	860	743	**1370**	2498	1299	**2370**	4298
3.33	**38**	100.4	243	**470**	878	749	**1380**	2516	1304	**2380**	4316
3.89	**39**	102.2	249	**480**	896	754	**1390**	2534	1310	**2390**	4334
4.44	**40**	104.0	254	**490**	914	760	**1400**	2552	1316	**2400**	4352
5.00	**41**	105.8				766	**1410**	2570	1321	**2410**	4370
5.56	**42**	107.6				771	**1420**	2588	1327	**2420**	4388
6.11	**43**	109.4				777	**1430**	2606	1332	**2430**	4406
6.67	**44**	111.2				782	**1440**	2624	1338	**2440**	4424
7.22	**45**	113.0				788	**1450**	2642	1343	**2450**	4442
7.78	**46**	114.8				793	**1460**	2660	1349	**2460**	4460
8.33	**47**	116.6				799	**1470**	2678	1354	**2470**	4478
8.89	**48**	118.4				804	**1480**	2696	1360	**2480**	4496
9.44	**49**	120.2				810	**1490**	2714	1366	**2490**	4514
		37.8		**100**	212.0			1093			1649
						538	**1000**	1832		**3000**	5432

NOTE—The numbers in bold face type refer to the temperature either in degrees Centigrade or Fahrenheit which it is desired to convert into the other scale. If converting from Fahrenheit degrees to Centigrade degrees the equivalent temperature will be found in the left column, while if converting from degrees Centigrade to degrees Fahrenheit, the answer will be found in the column on the right.

Compliments of
American Refractories Institute
Oliver Building, Pittsburgh, Pa.

INTERPOLATION FACTORS

C.		F.	C.		F.
0.56	1	1.8	3.33	6	10.8
1.11	2	3.6	3.89	7	12.6
1.67	3	5.4	4.44	8	14.4
2.22	4	7.2	5.00	9	16.2
2.78	5	9.0	5.56	10	18.0

Items of Interest

The Busmann Manufacturing Company has issued a twelve page folder which is a Hand Book On Fuses. The folder is very attractive and illustrates in a very complete manner how to eliminate and avoid troubles in connection with fuses. If you will address the Bussmann Mfg. Co. University at Michigan, St. Louis, they will be glad to forward you this hand book.

The Trumbull Mfg. Co.'s bulletin Trumbull T. Controlite covering the Theater Control board is a very handsome twelve-page booklet describing a combined switchboard and dimmer bank. Apply for Controlite bulletin February, 1927.

A thirty-two-page catalogue describing motor maintenance equipment is just off the press and is being distributed to the trade by the Martindale Electric Company, 1260 West 4th street, Cleveland, Ohio. This catalogue is known as number 8, April, 1927. The carbon brush maintenance and trouble chart, which is an analysis of causes and effects of brush and commutator troubles in direct current motors and generators, compiled by E. H. Martindale is worthy of every electrical engineer and superintendent's serious consideration. This catalogue is furnished upon application.

The Baker-Raulang Company of Cleveland, manufacturers of Baker electric tractors, trucks and cranes, have just announced the appointment of Blake C. Hooper as Manager of Railroad Sales. Mr. Hooper has been connected with the Baker organization for several years in his position as Secretary-Treasurer of the Minnesota Supply Company in St. Paul, who are Baker representatives in that territory.

He is a graduate mechanical engineer, having attended Armour Scientific Academy and Armour Institute of Technology. Upon leaving college he entered the service of the Rock Island Railroad, and left there in 1908 to take a position in the Drafting Department of the Railway Materials Company, Chicago, Ill. He was Assistant Superintendent of their Toledo, Ohio plant until June, 1909, returning to their general offices at Chicago as Mechanical Engineer and later as Plant Superintendent.

In 1912, Mr. Hooper resigned to enter into the railway supply field, and has been engaged in selling technical products to railroads since that date, with the exception of the period of the war during which he served in the army with rank of captain.

The Chicago Fuse Manufacturing Company, manufacturers of Union and Gem Fuses and Conduit Fittings, announce the appointment of Mr. W. A. Wilcox as District Sales Manager with headquarters at St. Louis. Mr. Wilcox will have charge of sales over southern Illinois, eastern Missouri, western Tennessee, Mississippi, Arkansas and Louisiana. Prior to this appointment, Mr. Wilcox was associated with the Economy Fuse and Manufacturing Company for more than eight years. He has a wide acquaintance in the electrical field and his long experience will be most valuable in his new work.

Harnischfeger Corporation, of Milwaukee, announces the opening of a Baltimore office at 1402 Lexington Building, under the management of Mr. Daniel J. Murphy, formerly Manager at Dallas, Texas.

The corporation builds electric traveling cranes; also gasoline, diesel, and electric driven shovels, draglines and trenching machinery.

Rust Engineering Company have a contract for designing and constructing a hot blast stove installation at The Delaware River Steel Company's blast furnace plant at Chester, Pa.

The Cleveland District Offices of Cumbustion Engineering Corporation, Ladd Water Tube Boiler Company, and Heine Boiler Company have been consolidated and will be located at 1107 Guardian Building.

Mr. Frank Henderson is Cleveland District Manager of these three associated companies.

The Philadelphia district offices of Combustion Engineering Corporation, Heine Boiler Co., and Ladd Water Tube Boiler Co. have been consolidated at 807 Bankers Trust Building, Philadelphia, Pa.

At the annual meeting of The Timken Roller Bearing Company, held at the main plant, Canton, Ohio, on Tuesday, April 19, all the present officers were re-elected for another year.

H. H. Timken is president; W. R. Timken, John G. Obermier, Marcus T. Lothrop, H. J. Porter and T. V. Buckwalter, are vice presidents; J. F. Strough is secretary and treasurer, and W. A. Brooks, is assistant secretary.

Directors are H. H. Timken, W. R. Timken, Marcus T. Lothrop, John G. Obermier, and J. F. Strough.

Only routine business followed the election. The financial report of the company was made public several weeks ago.

The Detroit Stoker Company, Detroit, announces the appointment of Mr. A. Kastello as district sales representative for their Eastern Canada and Montreal, Quebec territories, with headquarters at 915 New Birks Building, Montreal. Mr. Kastello is a well known Canadian engineer, having served for many years with different railway companies in Canada in the capacity of Mechanical Engineer and Power Plant Efficiency Engineer.

During the war he was with the Dominion Government as Mechanical Superintendent in the Department of Public Works, having charge of a very large explosive plant. Mr. Kastello has also acted in the capacity of Consulting Engineer on many power plant problems for various Canadian Industries.

Frank D. Mahoney, commercial manager of West Penn Power Company, has been elected vice president, according to an announcement by President G. M. Gadsby. Mr. Mahoney has been commercial manager since 1922. During the war he served as

consulting engineer to the Ordnance Department of the government and later as assistant to the director of construction of the United States nitrate plants at Muscle Shoals, Toledo and Cincinnati.

Mr. Mahoney was born in Fond du Lac, Wis., 38 years ago. He was educated in engineering at University of Wisconsin. Among his earlier positions were junior engineer and assistant electrical engineer of the American Gas Company at Philadelphia.

Following the war Mr. Mahoney joined the operating forces of the Alabama Power Company at Birmingham, Ala., resigning from that position to become affiliated with West Penn Power Company. He lives at 6216 Jackson Street.

The Forged Steel Wheel Company at Butler, Pa., has just purchased a 10 ton, 80 ft. 5 inch span Electric Overhead Traveling Crane, from the Cleveland Crane & Engineering Co., Wickliffe, Ohio. This crane will be equipped with General Electric Company's Mill type Motors and Cutler Hammer Manufacturing Company's magnetic control.

Mr. Rufus Bolt, who was employed at the Donner Steel Company as Superintendent of the rolling mills, died suddenly Wednesday, April 27th, 1927. Mr. Bolt was formerly connected with the Youngstown Sheet & Tube Company, Youngstown, Ohio.

At the research laboratory of the Westinghouse Electric and Manufacturing Company a most interesting phenomena occurred quite recently. In searching for some improvement in materials a by-product was obtained. It was some pure iron by distillation. Sounds strange, doesn't it? but the iron was boiled, evaporated and condensed like so much water. In the process the iron to be treated is put in a tube of refractory material and the air exhausted to about the vacuum obtained in an incandescent lamp. There the metal is isolated from air and from everything else. Electric current is used to heat it, but no electrodes are needed to get the energy to it. High frequency currents are used external to the tube, and currents are induced in the material sufficient to heat it to the vaporization point. What commercial uses for this iron is not known at the present time, since no definite application has been found as yet.

The Cleveland District Section concluded their Spring program with a visit to the factory of the E. H. Martindale Company, at Cleveland, Ohio, Saturday, April 23rd, 1927. The Martindale Company acted as host at a very elaborate dinner, Mr. E. H. Martindale presented a most interesting paper covering the subject of "Motor Maintenance."

The use of welding as a means of construction of factory and other plant buildings is to be adopted by the General Electric Company in future building programs, it has been announced by that company. The reason given for this policy is the fact that a study of structural design has shown that company conclusively that the welded structure can be made with less material than the riveted structure for the same loads.

The General Electric Company feels that its experience with welding indicates conclusively that, as soon as shop methods are developed, it will be possible to fabricate buildings by the use of welded joints cheaper than they can be fabricated by the use of riveted joints. This, it is expected, will lead to the use of welding as a means of economy and, in the future, it will be General Electric policy to use this type of structure wherever possible.

Those in charge of General Electric building plans make it plain that there is no conflict between welding and riveting at the present time, each having its own sphere and continuing to be used. The feeling is, however, that, as welding becomes cheaper than riveting, it will supplant it.

A new line of steel mill motors, to be known as the MD-400 series, is announced by the General Electric Company. These motors, designed in collaboration with the standards committee of the association of Iron & Steel Electrical Engineers, fully meet the specifications of that body and are the first motors on the market to meet the new standards.

The motors are of the roller bearing type, in compliance with the standardization rules. The roller bearings will be used as standard, although sleeve bearings can be supplied at the option of the purchaser.

The new line involves improved mechanical construction, more efficient use of materials and a refinement of details, when compared with the superseded line of MD-100 motors. A greater adaptability to severe service conditions is also claimed. Parts are more accessible and, at the same time, are better protected. The bearing construction for either sleeve or roller bearings incorporates new and valuable features.

The outstanding qualities are listed by General Electric as follows:

1. Heat-resisting insulation (mica and asbestos) conforming to A.I.E.E. Class "B" insulation specifications.
2. Ability to commutate high overloads.
3. Very low WR^2 to permit exceedingly rapid acceleration and frequent reversals.
4. Ready accessibility of each part.
5. Great mechanical strength of individual parts and exceptional security of the whole structure.

Two-pole switches with solid neutral block for use on three wire grounded systems have just been developed by the Westinghouse Electric and Manufacturing Company in sizes running from 30 to 600 amperes. This design of switch provides an economic switch arranged to utilize the advantages of reduced size made possible by using solid neutral without the third switch blade, the size being reduced to that of a standard two wire switch.

The 30 ampere size switch is of the "00" type, the 60, 100 and 200 ampere sizes of the WK-62 type, and the 400 and 600 ampere sizes of the WK-60 type. All the types up to 200 amperes may be supplied with end or removable end adapted to a meter trip when it is desired to mount the meter in conjunction with the switch. This new two-pole switch will be shown at the American Mining Congress.

A contract for substation equipment with the Milwaukee Electric Railway and Light Company, has just been given to the Westinghouse Electric and Manufacturing Company. This contract calls for 2—1500 kw. and 2—500 kw., 60 cycle railway con-

verters, transformers and automatic switching. The equipment will be used to supply 600 volt d-c. power to the railway system which is to be changed over from the present 1200 volt operation.

This last change completes the change-over of the entire system to 600 volt operation. The equipment included in this order is to be used on what is known as the East Troy and Burlington branches of the system. Due to the length of these branches, it was necessary to build 5 new substations, in order that sufficient power could be supplied at the reduced voltage. The equipment included in the above order will be used in these stations together with some that was in possession of the customer at the time the change-over was made.

The automatic switching supplied on this order includes equipment for the full automatic control (undervoltage starting and light load stopping) of the five new 500 kw. substations on the East Troy and Burlington branches.

The two 1500-kw. railway converters included in this order are to be installed at 36th Street station and Oakland Avenue station, each one of which will be full automatic controlled. In addition these two stations are to be equipped with Westinghouse Audible Type Supervisory Control Equipment. Control and supervision of seven feeders circuit breakers, two lockout relays and two signal circuits at the 36th Street station and six circuit breakers, two lockout relays and two signal circuits at Oakland substation, will be accomplished with this equipment.

On completion of this installation the Milwaukee Electric Railway and Light Company will have seven substations under full automatic control using Westinghouse switching throughout.

The constantly increasing use of higher and still higher voltages for electrical distribution systems and the tremendous capacity for the present day sources of supply, are creating a persistent demand for more adequate protective grounding circuits and equipment. The improvements most urgently needed are better mechanical protection for the ground wires and their connections and better methods of connecting the grounding wires to water pipes and conduits, especially conduits having non-conducting coatings.

Crouse-Hinds Company, of Syracuse, New York, announces a complete line of Groundulets. This material they are prepared to furnish for the installation of the most approved types of safety circuits and particularly those types of circuits where the ground wire is enclosed in iron conduit throughout its entire length, from the entrance switch to the water pipe.

Type GCA has been designed for making connections to water pipes in such a manner that a thoroughly secure mechanical and electrical connection is provided, and at the same time, the ground wire and its connections are fully protected from mechanical injury, and the conduit itself, as well as the wire contained within it, are electrically connected to the water pipe. In this type of Groundulet, the body portion is in one piece and fully meets all of the requirements of the National Electric Code and is relatively inexpensive.

In the type GCE, the body portion is made in two parts, one of which is attached to the water pipe and the other to the conduit protecting the ground wire. After the two parts have been separately installed, they are fastened together with a bolt, the soldering lug for the ground wire being at the same time clamped between the two portions, and as the two part swivel about the clamping bolt, the protective conduit may approach from any direction. This Groundulet is constructed with an extra large strap of a new and improved type not found in any other make of ground fitting, and with an especially designed type of fastening which permits applying adequate clamping pressure.

They have also developed a Groundulet bushing for making connections to conduits. This Groundulet bushing takes the place of the ordinary bushing within the main switch box and is so designed that when the grounding leads are attached thereto, the bushing is securely locked upon the conduit and a positive and adequate electrical connection is established, while at the same time all the grounding leads are enclosed in the switchbox and are, therefore, protected from mechanical injury, and the fire hazard is practically eliminated. These bushings are made of brass and the extra flexible jumpers designed for this use are provided with fire-resisting insulation.

All these materials have been approved by the Underwriters' Laboratories.

The dates for the sixth International First-Aid and Mine Rescue Contest, recently announced as to be held in Pittsburgh, Pa., have been fixed for the three days, August 30 and 31, and September 1. The first-aid contests, in which teams from coal and metal mines, quarries, and oil-producing and refining companies from numerous States will compete, will be held at Duquesne Garden. The mine-rescue meet, which will also be participated in by teams from widely-scattered mining communities, will be held on the campus of Carnegie Institute of Technology. The contest will be given under the auspices of the United States Bureau of Mines, Department of Commerce, in co-operation with the Pittsburgh Chamber of Commerce.

Various prizes will be awarded the teams which, in the opinion of the judges, prove themselves most efficient in first-aid and mine-rescue methods. Each first-aid team will be composed of six men, including a "patient." Each team will be required to perform three or more definite problems in first-aid, calling for the treatment of injuries and the proper handling of the patient. The patient, assumed to be suffering from electrical shock, arterial bleeding, broken bones, or other injury, will be given the first-aid treatment prescribed in the manual of the United States Bureau of Mines. The events will be judged by doctors and expert laymen skilled in first-aid training and conversant with the Bureau of Mines first-aid standards.

The competing mine-rescue teams will be composed of five men provided with oxygen breathing apparatus and other necessary equipment used by rescue crews in coal and metal mines. The teams will be required to work out in a specially prepared smoke room a practical problem such as is likely to be encountered in underground rescue operations.

The International First-Aid and Mine-Rescue Contests are held each year under the auspices of

the Bureau of Mines, with the co-operation of the National Safety Council, The American National Red Cross, and various mine operators' associations and miners' organizations. Employees of mines, quarries, and metallurgical plants, and workers in the oil and gas industry are eligible to participate in the contest. More than 200,000 workers in the different mineral industries have been trained in first-aid or mine-rescue methods by the Bureau of Mines. A feature of the meet will be the awarding of the Congressional medal, given annually to the teams of miners adjudged most thoroughly skilled in first-aid and mine-rescue methods.

The Bureau of Mines has made the First-Aid and Mine-Rescue Contest the occasion for calling in from the field all of its mine-safety instructors for the purpose of giving them a brief, intensive course of instruction in the latest mine-safety and accident-prevention methods. For a period of two days immediately following the contest, these men, summoned from the principal mining communities of the United States, will be coached carefully in the latest safety kinks approved by the Bureau of Mines.

It is with the deepest regret that we announce the death of Mr. Henry Y. Stuckey, Chief Engineer of the Alliance Machine Company, Alliance, Ohio, which occurred in Asheville, N. C., on Sunday, May 9th.

Mr. Stuckey was humanity's friend, irrespective of creed or color, always willing and more than willing to do his part and these were the predominating traits in his character. His life was above reproach in whatever environment he found himself. He was a good home man and a good citizen.

We know that all with whom he was acquainted —and they were many—will deeply feel his departure.

The Combustion Engineering Corporation at 200 Madison avenue, New York, is distributing a paper presented before the International Conference on "Bituminous Coal" covering the subject of "Burning Powdered Coal Under Steam Boilers," by Henry Kreisinger, Research Engineer, Combustion Engineering Corporation. The author's paper covers Refractory Lines Furnaces, Effort to Prevent Flame Impingement, Hollow Refractory Walls, Water Cooled Furnaces, Fin Tube Furnace Walls, Intensive Mixing in Furnace Important, Furnace Temperatures, Effect of Preheated Air on Furnace Design, Steam Generating Unit at Lakeside Station, Steam Generating Unit at Kips Bay Station, Steam Generating Unit at Fordson Plant, Combustion Steam Generator, Steam Generating Unit at Calumet Station, Rate of Heat Absorption in Furnace, Turbulant Mixing in Furnace. The paper is illustrated as follows: Figure 1—A cross section of fin furnace wall, Figure 2—Twelve hundred pound pressure unit, Lakeside Station, The Milwaukee Electric Railway and Light Company, superheaters in side walls of furnace; reheater in rear wall; fin tubes in furnace front wall, plain tubes under arch and in front wall above arch. Figure 3—Steam Generating Unit, Kip's Bay Station, New York Steam Corporation; all furnace walls of fin tube construction. Figure 4—Steam Generating Unit, Fordson Plant, Ford Motor Company; fin tubes and radiant superheaters in the side walls; convection superheater in first bank of boiler tubes; arches protected with plain tubes. Figure 5—Combustion Steam Generator, Taylor Brothers Steel Plant, Manchester, England. Figure 6—Couch burner for turbulent mixing in furnace. Figure 7—Combustion Steam Generator, Calumet Station, Commonwealth Edison Company; all furnace walls of fin tube construction. If you are interested in this paper, write the International Combustion Engineering Corporation, International Combustion Building, Madison avenue, New York, N. Y.

The fourth annual banquet of the Cambria-Maryland Bowling League, composed of operating Superintendents and Executives of the Bethlehem Steel Company, was held at Mountain View Hotel, on Crest of Huckleberry Hill, Greensburg, Pa. The Bowling Tournament held by these two plants was one of the most exciting in the history of the two organizations, the Cambria Plant bowlers winning by four pins. The Cambria team is composed of H. A. Marley, L. F. Quigg, W. E. Steiner, H. R. Coulson, A. W. Huedner, I. W. Penrod. The Maryland team was represented by A. T. Halstead, D. E. Stringer, J. F. Oaks, R. S. Wilson, C. Royston, W. H. Smiley. About 125 Operating Superintendents attended the outing and banquet.

The many requests by colleges for information regarding the new Delta-Star 750,000 volt testing laboratory made us realize that students desire a better knowledge of the fundamentals of electrical testing.

To save time for all concerned, Delta-Star Electric Company of Chicago has inaugurated a way of imparting this information by group method. The colleges arrange to have the students in charge of their professors, visit the laboratory on a given date.

The Delta-Star engineers are thus enabled to give the desired information, make tests and such demonstrations as will be both interesting and informative to the students.

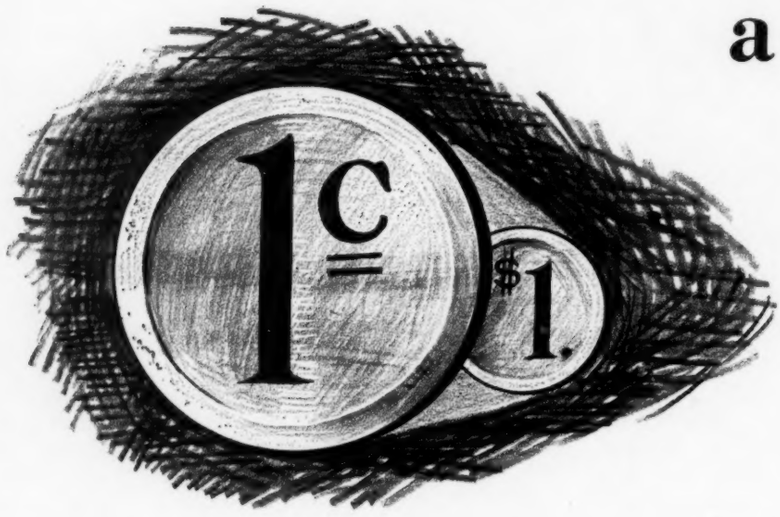
A trench hoe equipped with goose-neck boom has been designed by Harnischfeger Corporation, Milwaukee, Wisconsin. This improved hoe is one of eight attachments which can be used on machines they are manufacturing. The goose-neck boom permits digging to a greater depth than is possible with the old straight type of boom.

The model 700 trench hoe, as illustrated, digs to a depth of 24 feet and has a working reach of 36 feet 6 inches.

Harnischfeger Corporation is equipping their 1 yard, and 1¼ yard machines with this improved type of boom. The 1 yard machine, model 600, with dipper teeth adjustments, cuts trench from 38 to 42 inches in width. The 1¼ yard, model 700, cuts trench from 46 to 52 inches in width. Any width of trench beyond 52 inches can be cut by shifting the course of the dipper. The dipper can be dumped from the front or bottom, and the dipper door is provided with a special patented locking device.

The Pittsburgh Transformer Company just recently issued bulletin No. 2064, which pictorially describes seven new installations of Pittsburgh Transformers. Pittsburgh Transformer Company, Pittsburgh, Pa., will be glad to honor any request for this bulletin.

Don't hide the Dollar with a Penny!



ONE man said to us "Brushes are the least of our troubles," whereas a close observation of the case revealed a heavy loss in K. W. H. due to faulty brushes—hiding the dollar with the penny.

This is only one case; we could cite many more where poor or wrongly applied brushes are slowly piling up production costs, wearing out commutators and decreasing the life of the motor.

Boxill-Bruel does not merely sell you brushes like you would buy nails—never—we offer a genuine brush engineering service.

We want to study your problem and provide the proper brush to remedy the trouble—perhaps we can help you.

Don't let the penny hide the dollars that may be possible from your equipment.

Write us.

BOXILL-BRUEL CARBON COMPANY

308 W. 4th ST., CINCINNATI, OHIO

BRANCH OFFICES

New York
507 Fifth Ave.

Pittsburgh
2126 Farmers Bank Bldg.
Sheveport, La.
Bennett Sales Co.

Chicago
80 E. Jackson Blvd.